Logistics Management Institute

Estimating Costs for Army Materiel Health Hazards

AR515R1

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Executive Summary

Health hazards are inherent in all U.S. Army materiel systems. If ignored, however, these hazards can cause serious injuries and illnesses to military and civilian operators throughout the life of the system. The medical costs for treating those injuries and illnesses can pose significant financial burdens to the Army and Veterans Affairs health care systems. For example, implementation of recommendations to control health hazards for an armored fighting vehicle evaluated by the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) will result in the Army avoiding potential medical and lost time costs of approximately $345 million over the life of the system.

For these reasons, Army health hazard assessment reports identify potential hazards in materiel systems and recommend methods for eliminating or controlling the hazards, based on a calculated risk assessment code. The reports do not provide the medical costs for injuries or illnesses that will result from the hazards—information that is necessary for materiel program managers to understand the hazards associated with their systems and to make informed decisions about corrective actions.

We developed a model that estimates medical costs for health hazards based on the risk assessment codes. Quantifying the costs of health hazards improves the understanding of a stated health risk and assists managers in making risk management decisions. Armed with medical costs for unabated health hazards, health hazard assessors and materiel system managers can better justify implementation of recommendations to eliminate or control those health hazards. Our model also provides invaluable information to health care system practitioners and other preventive medicine personnel.

We recommend the following:

- The Health Hazard Assessment Office of USACHPPM should adopt the model to estimate medical costs for unabated health hazards and incorporate these costs into their health hazard assessment report recommendations.

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- The Army materiel program managers should use the results of the model to prioritize and abate health hazards associated with their systems.

- The Army preventive medicine community and the USACHPPM should adopt the model for use in all prevention-related programs to estimate the medical costs potentially avoided by individual mission program recommendations.

- The Army preventive medicine community and the USACHPPM should use the model component outputs as performance metrics for assessing preventive medicine programs and preventive medicine products.

- The USACHPPM should invest in improving the model by

  - incrementally improving the model component variables,

  - incorporating new model components for pollution prevention and health hazard assessment,

  - improving the source data used in the model, and

  - developing appropriate variables to estimate hazard-specific costs.

These actions—adopting the model, including the results in health hazard assessment reports, and using the results for abatement prioritization—will better enable the Army to eliminate or control materiel health hazards and control life-cycle costs. Furthermore, applying the model to other areas of preventive medicine will provide invaluable quantitative cost savings and cost avoidance information to Army decision-makers.

Contents

Chapter 1 Introduction 1-1

The Need for Estimating Costs 1-1

Army Materiel Health Hazards 1-1

Performing Health Hazard Assessments 1-3

The Assessment Program 1-4

Quantifying Health Risk 1-5

Report Organization 1-6

Limitations of the Model 1-7

Chapter 2 The Basic Model for Estimating Medical Costs 2-1

The Six Cost Components 2-2

Rationale for the Components 2-2

Assumptions 2-3

Potential Uses of the Model 2-3

Use of the Existing Outputs 2-4

Preventive Medicine Applications 2-4

Common Variables 2-5

Determining the Number of People Exposed to the Hazard (N_e) 2-6

Determining the Hazard Severity Factor (S_k) 2-7

Chapter 3 Estimating Clinic Costs 3-1

The Equation 3-1

Specific Variables for Clinic Costs 3-1

Clinic Visit Constant (V_e) 3-2

Incidence of Injury or Illness (I_i) 3-2

Number of Clinic Visits (N_c) 3-3

OTHER USEFUL OUTPUTS 3-3
Number of Persons Injured or Ill (N_i) 3-3
Number of Clinic Visits (N_v) 3-4
AN EXAMPLE CALCULATION 3-4
SUMMARY 3-5

Chapter 4 Estimating Hospitalization Costs 4-1
THE EQUATION 4-1
SPECIFIC VARIABLES FOR HOSPITALIZATION COSTS 4-2
Incidence of Hospitalization (I_h) 4-2
Average Number of Days in Hospital (D_{hd}) 4-2
Hospitalization Population Distribution (D_{ho}) 4-3
OTHER USEFUL OUTPUTS 4-3
Number of Persons Hospitalized (N_{ph}) 4-4
Number of Hospital Days (N_h) 4-4
AN EXAMPLE CALCULATION 4-5
SUMMARY 4-6

Chapter 5 Estimating Lost Time Costs 5-1
THE EQUATION 5-1
SPECIFIC VARIABLES FOR LOST TIME COSTS 5-2
Incidence of Lost Time (I_l) 5-2
Average Number of Days of Lost Time (D_{ld}) 5-3
Lost Time Population Distribution (D_{lt}) 5-3
OTHER USEFUL OUTPUTS 5-4
Number of Persons Losing Time (N_{pl}) 5-4
Number of Lost Workdays (N_l) 5-4
AN EXAMPLE CALCULATION 5-5
SUMMARY 5-6

Chapter 6 Estimating Disability Costs 6-1
THE EQUATION 6-1
SPECIFIC VARIABLES FOR DISABILITY COSTS 6-2
Incidences of Disability 6-3

VA Disability Adjustment Factor (T_v) ... 6-4
VA Disability Population Distribution Factor (D_v) ... 6-4
Disability Compensation Factors ... 6-4
OTHER USEFUL OUTPUTS ... 6-5
AN EXAMPLE CALCULATION ... 6-6
SUMMARY ... 6-7

Chapter 7 Estimating Rehabilitation Costs ... 7-1
THE EQUATION ... 7-1
SPECIFIC VARIABLES FOR REHABILITATION COSTS ... 7-2
Incidence of VA Disability (I_v) ... 7-2
VA Disability Adjustment Factor (T_v) ... 7-2
Eligible VA Disability Population Distribution Factor (D_r) ... 7-2
VA Qualification Factor for Rehabilitation (Q_r) ... 7-3
VA Rehabilitation Benefit Factor (B_r) ... 7-3
OTHER USEFUL OUTPUTS ... 7-3
AN EXAMPLE CALCULATION ... 7-4
SUMMARY ... 7-5

Chapter 8 Estimating Death Costs ... 8-1
THE EQUATION ... 8-1
SPECIFIC VARIABLES FOR DEATH COSTS ... 8-1
Number of Deaths (N_{de}) ... 8-2
Death Benefit and Expenses (B_{de}) ... 8-2
OTHER USEFUL OUTPUTS ... 8-2
AN EXAMPLE CALCULATION ... 8-3
SUMMARY ... 8-3

Chapter 9 Cost Summary for a System with Multiple Health Hazards ... 9-1
A RECAP OF THE MODEL ... 9-1
TOTAL COSTS ... 9-2
Use of the Model for a System with Multiple Hazards ... 9-2
Cost Summary ... 9-2
Individual Component Output Summary ... 9-4

Chapter 10 Increasing the Model's Value 10-1
EXPANDING MODEL APPLICATION 10-1
Other Preventive Medicine Programs 10-1
Component Outputs 10-2
IMPROVING THE MODEL 10-2
Incorporating New Components 10-2
Improving Source Data 10-3
Estimating Hazard-Specific Costs 10-4
SUMMARY 10-4
Chapter 11 Recommendations 11-1
APPLYING THE MODEL 11-1
IMPROVING THE MODEL 11-2
References
Bibliography
Glossary

FIGURES

Figure 1-1. Common Health Hazards Encountered with Army Materiel 1-2
Figure 1-2. Addressing Health Hazards During the Acquisition Process 1-4
Figure 2-1. The Basic Model for Estimating Medical Costs for a Single Hazard 2-1
Figure 2-2. The Common Variables for Estimating Medical Costs 2-5
Figure 9-1. The Basic Cost Model with Individual Components and Outputs 9-1

TABLES

Table 1-1. Risk Assessment Code Matrix 1-5
Table 3-1. System-Assigned Risk Levels 3-2
Table 4-1. Factors for Average Number of Days in Hospital (days/person) 4-3

Table 4-2. Factors for Hospitalization Population Distribution (D_{ho}) by Length of Stay in Hospital for System Risk Categories 4-3

Table 5-1. Factors for Average Number of Days of Lost Time (days/person) 5-3

Table 5-2. Factors for Lost Time Population Distribution (D_{lt}) by Days of Lost Time for System Risk Categories 5-3

Table 6-1. Factors for Disability Population Distribution (D_v) by Degree of Disability for System Risk Categories 6-4

Table 6-2. VA Disability Compensation Factors by Degree of Disability (B_V) (dollars/month/person) 6-5

Table 9-1. System X Health Hazards and Associated Risk Indices 9-2

Table 9-2. Life-Cycle Costs of Unabated Health Hazards for System X 9-3

Table 9-3. Individual Component Outputs by Hazard—Yearly Basis 9-5

Preface

It seems intuitive that health hazard intervention and prevention activities must significantly ease the burden on the health care system by reducing deaths, disabilities, lost time away from the work site, hospitalization, clinical medical costs, injuries and illnesses, and rehabilitation. For years, however, the preventive medicine community has needed a way to estimate the actual costs avoided. Without such a tool, one could expect significant medical costs to arise from flawed planning or from a shortage of useful information available to decision-makers.

The model described in this report—which quantifies the costs that prevention avoids—was developed specifically to assist the U.S. Army estimate materiel system health hazard costs based on the probability of a hazard occurring and the severity of that hazard. We linked industry risk levels to system risk levels. We linked health hazard categories with potential medical outcomes and then used this information to determine incidence, distribution, and other rates for injury, lost time, hospitalization, disability, etc. The result is a model that quantifies health hazard costs. This provides a better understanding of a stated health risk and the likely monetary impact if no preventive or corrective actions occur.

We present the model's components and their outputs as a starting point. Other health care practitioners may know of additional components to incorporate into the model, and improving the source data will increase the model's accuracy. (We maintain the detailed data used in determining the variables described in this report in our organizational files and will provide these data under separate cover.)

Yet the model, while not perfect or complete, is nevertheless applicable to other preventive medicine areas. The preventive medicine community should not wait for the development of a perfect or complete model. Given the current political and cost-constrained environment, it is critical to begin quantifying health hazard costs now.

Chapter 1
Introduction

THE NEED FOR ESTIMATING COSTS

Health hazards are inherent in all U.S. Army materiel. If ignored, these hazards can cause serious injuries and illnesses throughout a materiel system's life cycle. The costs for treating such injuries and illnesses pose a significant financial burden to military health care systems, and the resulting lost time degrades productivity and unit readiness.

For these reasons, health hazard personnel conduct assessments of new or improved materiel. The assessments currently evaluate

- the types of hazards that exist,
- the injuries or illnesses likely to result from the hazards,
- the level of risk for each hazard, and
- the corrective actions needed to eliminate or abate the hazard.

They report this information to the materiel program managers, who are responsible for the development and life-cycle management of the materiel system.

These assessments, however, do not currently report the medical costs for injuries and illnesses that will result from the hazards. Without this cost information, materiel program managers may not fully understand the importance of their system's health hazards and cannot make informed tradeoff decisions about corrective actions.

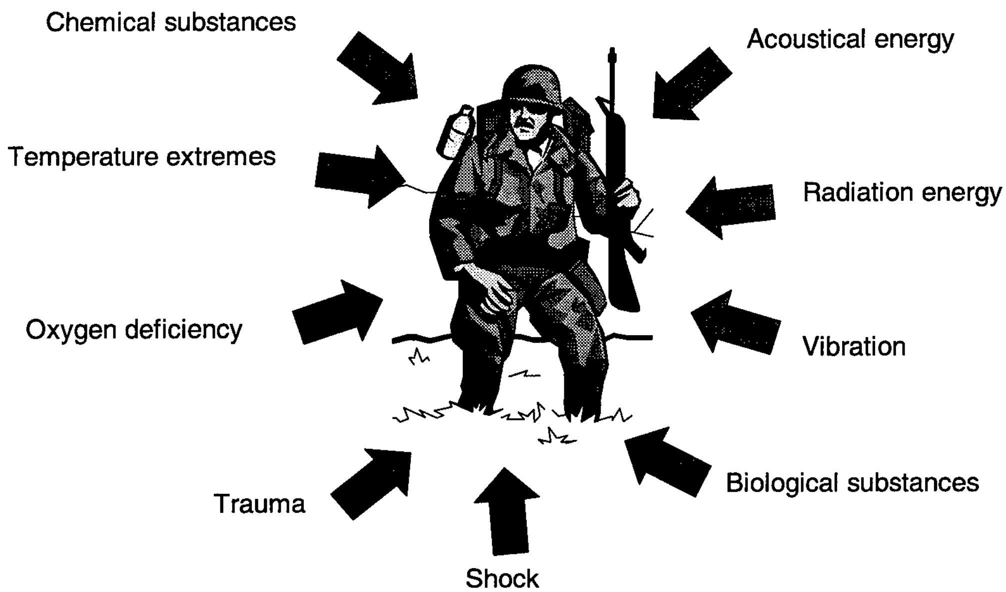
In this report, we present a model for use by health hazard assessment personnel to estimate the medical costs of such hazards to system operators. The model estimates costs in a materiel system's operations and support phase. It does not provide cost estimates for hazards in the other phases of the life cycle of the system, estimate the costs of corrective actions, or address pollution prevention issues.

ARMY MATERIEL HEALTH HAZARDS

Figure 1-1 depicts common health hazards of Army materiel. Health hazard assessments use these categories, which are described in Army Regulation 40-10,

Health Hazard Assessment Program in Support of the Army Materiel Acquisition Decision Process. [1]

Figure 1-1. Common Health Hazards Encountered with Army Materiel



That regulation gives the following further descriptions of the nine hazard categories:

- *Chemical substances.* Chemical substances become a concern when their concentration level exceeds acceptable limits and adverse health effects occur. In military systems combustion products are good examples of complex chemical substances that produce adverse health effects. Exposure to many chemical substances can cause illness, injury, and degradation of soldier performance.

- *Acoustical energy.* The hazards acoustical energy presents include continuous noise from engines and helicopter rotors, impulse noise from shoulder-fired weapons, and blast overpressure created from firing mortars, towed artillery (free-field energy wave), and heavy weapons on crew-served vehicles (complex energy wave). Exposure to these hazards can lead to hearing loss, lung injury, and performance degradation.

- *Temperature extremes.* These hazards include the human health effects associated with high or low temperatures that can become worse by using a materiel system. Exposure to these hazards can cause climatic injuries to include heat and cold stress. The hazards can lead to injury, illness, and performance degradation.

- *Radiation energy.* These hazards include ionizing and nonionizing radiation. Ionizing radiation can cause ionization when interacting with living or inanimate matter. Ionizing radiation hazards include alpha and beta particles, gamma rays, x-rays, and neutrons. Nonionizing radiation refers to emissions from the electromagnetic spectrum that have insufficient energy to produce ionization of molecules. Nonionizing radiation hazards include ultraviolet, visible, and infrared light, and radio frequencies, including microwaves. Lasers emit amplified electromagnetic radiation within the nonionizing spectrum. These hazards can result in illness, injury, and performance degradation.

- *Oxygen deficiency.* This hazard resulting from oxygen displacement in crew or confined spaces can result in shortness of breath and impaired coordination and judgment, with progression to unconsciousness and death.

- *Vibration (whole body and segmental vibration).* These hazards result from contact between the human body and a mechanically oscillating surface. These hazards can result from riding in or driving vehicles, equipment, and aircraft, and operating some hand-operated tools. The hazards can cause musculoskeletal injury and cumulative trauma disorder, resulting in performance degradation.

- *Trauma (blunt, sharp, or musculoskeletal).* These hazards occur because of sharp or blunt object impact to the eyes or body surface, or because of musculoskeletal injury resulting from lifting heavy objects such as projectiles or ammunition boxes. These hazards can result in severe injury and degradation of performance.

- *Biological substances.* These substances can result from lack of sanitation in ventilation systems, water, human waste disposal, food handling, and personal hygiene. The hazards include exposure to micro-organisms, toxins, and enzymes, and can result in illness and degradation of individual and unit performance.

- *Shock hazards.* These are a result of the delivery of a mechanical impulse or impact to an individual. This often results from individual contact with a medium that is accelerating or decelerating. Examples include the opening forces of a parachute harness and the forces delivered to the body as the result of weapon recoil. Shock hazards can result in severe injury and performance degradation.

Performing Health Hazard Assessments

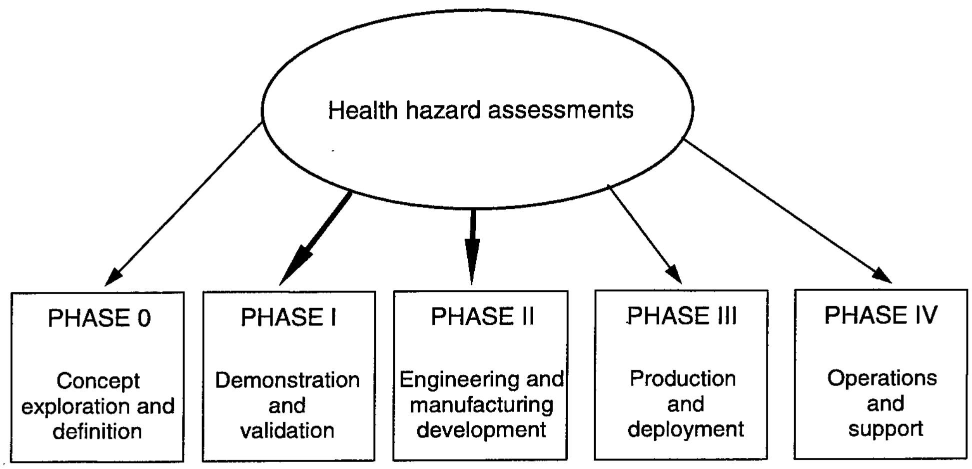
The goal of the Army's health hazard assessment program is to identify, assess, and eliminate or control hazards such as those described above that are associated

with weapon systems, munitions, equipment, clothing, training devices, materiel systems, and information systems.

The Assessment Program

The Army performs health hazard assessments in all phases of the acquisition process (see Figure 1-2). Hazards eliminated or controlled early in the process will require less attention later in the life cycle. The two thicker arrows in Figure 1-2 show the two critical phases for health hazard assessments within the acquisition process.

Figure 1-2. Addressing Health Hazards During the Acquisition Process



Optimally, identification of health hazards occurs in phase 0, concept exploration and definition, however, that is not always possible. The goal is to resolve all health hazard issues during phase I, demonstration and validation, and before the end of phase II, engineering and manufacturing development. Early consideration of health hazard issues allows for a greater potential to influence design and process changes to prevent health hazards. This approach avoids program delays and costly modifications to the materiel or equipment already produced and/or fielded.

In addition to supporting decisions on eliminating and/or reducing system hazards, Army health hazard assessment reports support the preparation of numerous acquisition-related documents and processes to include

- manpower and personnel integration (MANPRINT) assessments,
- system MANPRINT management plans,
- test and evaluation master plans,
- detailed test plan,

- market investigations,
- safety releases,
- system technical and training publications,
- milestone decision reviews,
- statements of work,
- requests for proposals,
- source selection evaluation boards, and
- integrated concept and process teams.

Quantifying Health Risk

Risk per se is a probability statement. As explained below, however, the term "health risk" combines the probability of exposure to a hazard and the severity of the potential consequences.

The Army assesses health risk with a risk assessment code (RAC) as illustrated in Table 1-1. The first step is to estimate the hazard severity (HS), the severity of the medical effects caused by exposure to a hazard. The next step is to estimate the hazard probability (HP), the probability of an operator being exposed to the hazard. The matrix cell where the values for hazard severity and hazard probability intersect shows the appropriate RAC.

Table 1-1. Risk Assessment Code Matrix

	Hazard probability				
Severity	A	B	C	D	E
I	1	1	1	2	3
II	1	1	2	3	4
III	2	3	3	4	5
IV	3	5	5	5	5

The four hazard severity categories are

- Category I—catastrophic,
- Category II—critical,

- Category III—marginal, and
- Category IV—negligible.

The five hazard probability levels are

- A—frequent,
- B—probable,
- C—occasional,
- D—remote, and
- E—improbable.

The resulting RAC may range from 1 (very high health risk) to 5 (very low health risk).

For example, a hazard of marginal severity (HS = III) with an exposure assessed as probable (HP = B) has a moderate overall risk (RAC = 3). The Glossary appended to this report defines the hazard severity and hazard probability categories, as well as other important terms.

Because health hazard assessors all use the RAC matrix for determining health risk, our intent was to develop a cost model with a basis in the RAC.

Although the severity categories and probability levels are the key drivers in the model and are derived from the RAC matrix, we could not use the severity and probability data in their descriptive form. We developed numerical values for the descriptive severity categories and probability levels for use in the model and validated them using practicing health hazard assessment experts from the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM).

REPORT ORGANIZATION

This report presents our model for estimating the costs of Army materiel health hazards. Chapter 2 explains the basic model. In it we present our rationale for selecting the various cost components, how we foresee the model being used, and future efforts necessary to improve the model. Chapters 3 through 8 focus on the model's six separate components:

- Clinic costs
- Hospitalization costs
- Lost time costs

- Disability costs
- Rehabilitation costs
- Death costs.

We discuss the rationale and assumptions for each of the six components, the data sources used, and an analysis of the data, and we provide the basic equation for each element. Chapter 9 provides a summary for a multiple-hazard system, Chapter 10 addresses increasing the model's value, and Chapter 11 provides our recommendations. Appendices list references, provide a bibliography of relevant sources, and define terms used in this report.

LIMITATIONS OF THE MODEL

This version of the model provides an average medical cost for an average health hazard, rather than for a specific health hazard. This approach was more feasible initially, even though it results in the loss of the specific hazard costs relating to specific medical outcome categories.

We do not include pollution prevention savings in the estimate of medical costs. We only consider potential dollar costs avoided for medical and lost time costs related to the illness or injury caused by exposure to the hazard.

We do not subtract out hazard abatement implementation costs associated with the actual implementation of health hazard assessment recommendations. These costs depend on the type of recommendation made and the degree of reduction of the health hazard. Costs may include those for potential publication or labeling, protective equipment, production process changes, engineering design, operation and maintenance, retrofitting, and disposal.

We believe that pollution prevention, hazard abatement, and other implementation costs are minimal compared to system procurement costs, when health hazard assessment recommendations are incorporated during system design.

Chapter 2
The Basic Model for Estimating Medical Costs

In this chapter we present an overview of the basic model for estimating the medical costs of unabated health hazards in Army materiel. We discuss the model's six basic components, the rationale for each, the model's outputs and potential uses, and its common variables.

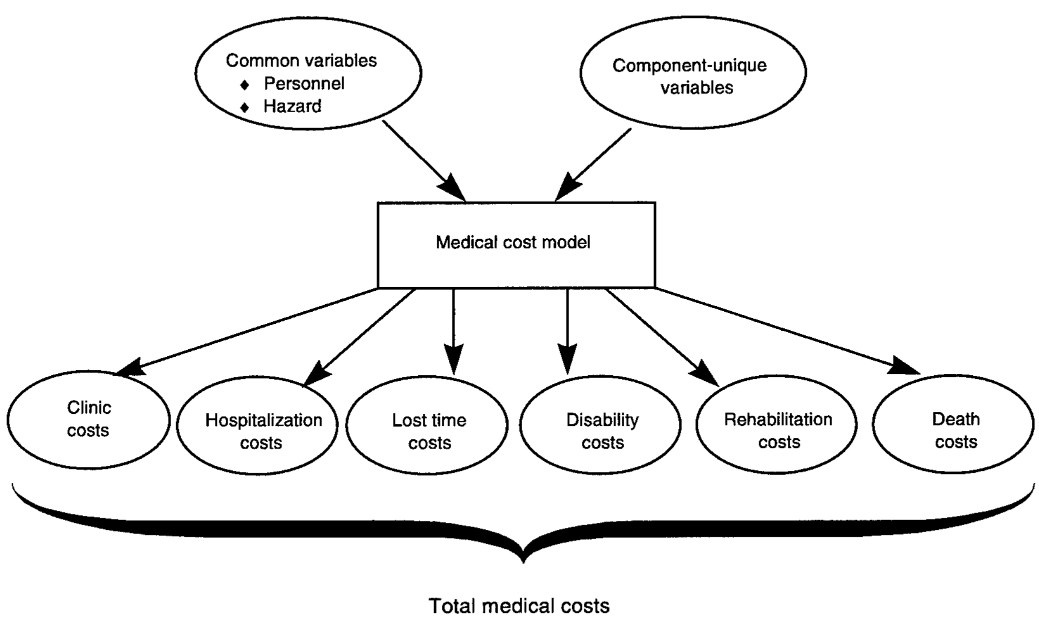
The basic model can be expressed in equation form as follows:

Hazard costs/year = clinic costs/year + hospitalization costs/year
+ lost time costs/year + disability costs/year
+ rehabilitation costs/year + death costs/year.

This general equation estimates medical costs for each health hazard identified for a system. The total medical costs for a system equal the sum of the individual hazard costs times the number of years in the life span of the system.

Figure 2-1 presents a diagram of the basic model showing the model's two common variables and six components. The common variables describe the number of people exposed to the hazard and the hazard severity. The model generates outputs for each of the six cost components: clinic, hospitalization, lost time, disability, rehabilitation, and death.

Figure 2-1. The Basic Model for Estimating Medical Costs for a Single Hazard



The total medical cost for the system is equal to the total costs potentially avoided if all health hazards are eliminated. If the health hazard recommendations are not implemented, the total medical cost equals the costs the Army could expect to incur due to injuries and illnesses resulting from exposure to these hazards.

THE SIX COST COMPONENTS

The six cost components estimate various types of medical costs associated with exposures to hazards that result in illness or injury.

The following are brief descriptions of each component:

- *Clinic costs.* Costs attributed to outpatient visits to a medical clinic or medical treatment facility by persons exposed to a hazard that resulted in illness or injury. [2]
- *Hospitalization costs.* Costs attributed to inpatient hospital stays by persons exposed to a hazard that resulted in illness or injury. [3,4]
- *Lost time costs.* Costs attributed to time away from the job by persons exposed to a hazard that resulted in illness or injury. [5]
- *Disability costs.* Costs attributed to active-duty temporary and permanent disability compensation and U.S. Department of Veterans Affairs (VA) disability compensation by persons exposed to a hazard that resulted in illness or injury. [6,7,8]
- *Rehabilitation costs.* Costs attributed to rehabilitation benefits received by eligible persons drawing VA disability compensation who were exposed to a hazard that resulted in illness or injury. [8,9]
- *Death costs.* Costs attributed to payment of insurance proceeds and the cost of casualty assistance, honor guard, burial, family, and other expenses, as a result of the death of persons exposed to a hazard that resulted in illness or injury complications.

RATIONALE FOR THE COMPONENTS

We selected the six cost components of the model to measure the outcomes that could happen to operator personnel as a result of an injury or illness. Although there are many system scenarios, only six basic events can occur when a soldier becomes ill or injured:

- Visit to a medical clinic for basic outpatient treatment, medication, and tests

- Visit to a hospital for inpatient observation, emergency or definitive treatment, and more detailed tests
- Loss of time away from the job due to clinic and hospital appointments, assignment to quarters, and inability to perform on the job as a result of illness or injury
- Disability, either immediately while on active duty or after discharge or retirement at a later date
- Rehabilitation because of disability
- Death as a result of exposure severity or complications.

We did not incorporate the costs to acquire and train personnel replacements for those persons who were injured or ill. We also did not incorporate performance degradation costs or the nonmonetary effect on readiness. These costs could be substantial.

ASSUMPTIONS

The two primary assumptions we made were that

- we could establish the incidence rates—the rate of injury or illness in a group over a period of time—based on historical industry data, and
- a medical assessor conducted the risk assessment properly.

We developed incidence rates from comparable industry data, because not all the required data were available or accessible via military sources. The assignment of a RAC with its associated hazard probability and hazard severity is the critical element of communicating risk to weapon, materiel, and equipment managers. If this assessment is not performed correctly, the cost modeling process will break down.

POTENTIAL USES OF THE MODEL

The primary use for the model is to determine a total system medical cost (the sum of the six individual cost components). The materiel program manager can use this information to establish priorities for health hazard abatement prior to fielding a system and to assess the impact on readiness once it is fielded.

Additionally, the model can estimate numerous other outputs as a result of exposure to a hazard resulting in illness or injury. Physicians, environmental engineers, environmental scientists, and other health care personnel can use these

outputs to assess the strengths and weaknesses of preventive health care. Selected component outputs of the model include estimates for the number of

- clinic visits,
- persons who are injured or ill,
- persons who are hospitalized,
- hospital days,
- persons losing time on the job,
- lost workdays,
- persons who are disabled,
- rehabilitation cases, and
- deaths.

Use of the Existing Outputs

These outputs are useful for understanding the details of the medical cost expenditures caused by exposure to a health hazard. For example, some of the outputs may show a direct relation to military readiness. Injuries or illness resulting from exposure to the hazards associated with a system may result in extensive lost time on the job by affected soldiers. This statistic is critical from a military readiness perspective. Soldiers away from the job decrease the readiness of their units. Additionally, extensive lost time may require the unprogrammed acquisition and training of replacement personnel.

Preventive Medicine Applications

While we developed the model for estimating medical costs of health hazards associated with Army materiel, it can be used in other areas of preventive medicine. The model estimates total medical costs based on the determination of a health risk; if a health risk can be determined, then a medical cost estimate can be made. Health risk determination is an important measure in other areas of preventive medicine. The following are just a few examples of how the model can be applied:

- Industrial hygienists and occupational health personnel can use the model to estimate medical costs for hazards associated with industrial production line operations.

- Environmental engineers and health risk assessors can use the model to estimate medical costs for hazards associated with the cleanup of hazardous waste sites. They can also use the model to assess other environmental health hazards from environmental pollution.

- Preventive medicine physicians, environmental science officers, sanitary engineers, and community health nurses can use the model to estimate medical costs for environmental hazards found on the battlefield.

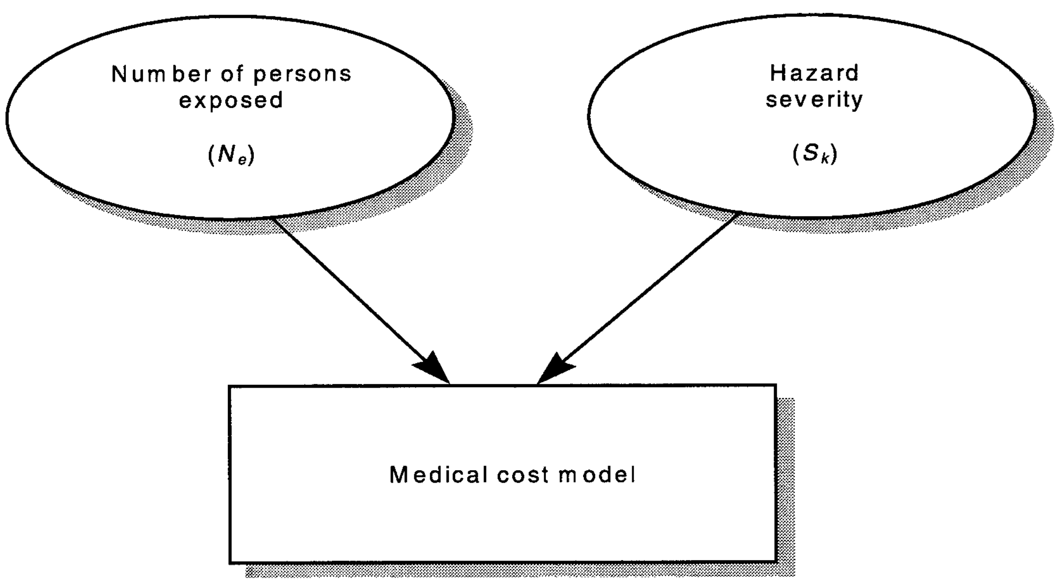
Additionally, the selected outputs can be considered measures of effectiveness for prevention programs. The bottom line for all prevention programs should be the reduction of illnesses and injuries, hospitalization, lost time, disabilities, and deaths.

COMMON VARIABLES

The common variables are the number of persons exposed (N_e) and the hazard severity factor (S_k). Five of the six model components (all but death costs) use the variables to estimate costs. Figure 2-2 shows these variables as input into the basic cost model. The product of these values provides the basis for the magnitude of the medical costs. The higher the product, the higher the expected medical costs.

Other variables are unique to specific medical costs for each component. We will discuss those variables later in the report when we address each model component. The unique variables include incidence and distribution rates for lost time, hospitalization, disability, and other costs.

Figure 2-2. The Common Variables for Estimating Medical Costs



Determining the Number of People Exposed to the Hazard (N_e)

The number of persons exposed to a hazard is the product of the number of systems, times the number of people per system, times the probability of exposure to a hazard. As discussed in Chapter 1, we based the probability of exposure to a hazard on the hazard probability category the medical assessor selected. The probability of exposure for multiple hazards from one system varies.

Equation 2-1 determines the number of persons exposed to a hazard.

$$N_e = P_e \times N_s \times N_{ps}, \qquad \text{[Eq. 2-1]}$$

where

- N_e = total number of persons per year exposed for the systems or items;
- P_e = probability of exposure per year, based on the determined hazard probability category;
- N_s = number of systems, the total number individual items of materiel; equipment, or weapon systems in Army inventory; and
- N_{ps} = number of persons per system, or crew size for system, or item.

As an example, using Equation 2-1 we can calculate for one of the Army's systems, which we will call System X, the number of persons per year exposed based on a health hazard associated with the system. System X has 10 health hazards: weapons combustion products, fire extinguishing agents, carbon dioxide, impulse noise, steady-state noise, cold stress, heat stress, oxygen deficiency (ventilation), nonionizing radiation, and ionizing radiation. For simplicity, in our examples we will work with a single health hazard, weapons combustion products. System X has a RAC of 1, a hazard severity of Category I, and a hazard probability of A for the weapons combustion products hazard.

The results of this calculation are used throughout this report with the applicable model cost components. For our example the known variables are

- P_e = probability of exposure = 0.9 per year (based on the determined hazard probability of A),
- N_s = number of systems = 7,400 systems, and
- N_{ps} = number of persons per system = 4 persons per system.

Then

$$N_e = 0.9/year \times 7{,}400\ systems \times 4\ person/system$$
$$= 26{,}640\ persons/year\ exposed.$$

Based on our calculation, 26,640 persons per year are exposed to the weapons combustion products hazard for this system.

Determining the Hazard Severity Factor (S_k)

We will now determine the hazard severity factor (S_k). The probability of exposure for multiple hazards from one system varies. For our example the known factor is

$S_k = 1$ *(based on the determined hazard severity Category I).*

With the number of people exposed determined and the hazard severity value defined, we now have the common variables for our model. These values are used throughout the report in our example calculations for costs.

In the next six chapters, we will explore each of the six cost components in detail. For each one we will do the following:

- Define the equations developed to estimate the costs
- Discuss component-unique variables and the rationale and assumptions made
- Discuss other useful outputs
- Perform an example calculation.

Chapter 3
Estimating Clinic Costs

In this chapter we present the component for potential yearly clinic costs as a result of exposure to a health hazard that results in injury or illness. We define the equations developed for estimating these costs; discuss the variables in determining clinic costs, the rationale and assumptions made, and other useful outputs; and perform an example calculation of clinic costs based on our System X example (using the single hazard).

The primary source of our illness and injury-related data was the U.S. Department of Labor Bureau of Labor Statistics survey on U.S. occupational injuries and illnesses in 1993. [10,11,12,13]

THE EQUATION

The general equation for clinic costs and its variables states that clinic visit costs (C_c) are simply equal to the product of the number of clinic visits (N_v) and the average cost per clinic visit (F_c). The general equation is provided as Equation 3-1:

$$C_c = N_v \times F_c, \qquad \text{[Eq. 3-1]}$$

where

C_c = cost of clinic visits,
N_v = total number of clinic visits, and
F_c = average fee per clinic visit.

The clinic visits variable (C_c) is dependent on two common variables and three unique variables. The two common variables, discussed in the previous chapter, are the number of people exposed and the severity of the hazard. The unique variables are a visit constant (V_e), the incidence of illness or injury (I_i), and the number of visits (N_c) by injured or ill persons.

The clinic visit fee (F_c) is an average cost based on the average of various types of clinic service visit fees. We found the average fee was $122 per clinic visit.

SPECIFIC VARIABLES FOR CLINIC COSTS

The specific variables we used in estimating clinic costs include the visit constant (V_e), the incidence of injury or illness (I_i), and the number of visits (N_c). We

assigned values for the visit constant and the number of visits. We selected illness and injury incidence rates from 1994 Bureau of Labor Statistics data. [10]

Clinic Visit Constant (V_e)

The visit constant (V_e) equals 0.75 and is based on exposure to a health hazard that results in illness or injury. It is assumed that if an exposure event occurs, then 75 percent of all persons exposed to the hazard will visit the clinic for an examination to determine whether any injury has occurred. (Environmental exposures received by soldiers in the Persian Gulf during Operation Desert Storm heightened the importance of being examined by a physician, even though medical symptoms of illness or injury may not be readily apparent after exposure to a hazard.) Often, an outpatient is actually seen in a screening or general clinic and then referred to an appropriate specialty clinic.

Incidence of Injury or Illness (I_i)

We selected incidence of illness and injury data from the 1994 Bureau of Labor Statistics data that we believe are representative of the range of illness and injury rates within the Army. Since these data were not military data, we selected industries with a high, medium, and low incidence of illness and injury. For example, the construction industry represents high-risk occupations (12.2 injuries or illnesses per 100 full-time workers per year), the transportation industry represents occupations with medium risk (9.5 injuries or illnesses per 100 full-time workers per year), and the service industry represents occupations with low risk (6.7 injuries or illnesses per 100 full-time workers per year). [10]

We analyzed each of the categories of materiel systems (see Table 3-1) to determine the appropriate illness and injury incidence rate. [10,14,15,16,17] We based our analysis on limited Army illness and injury data and the experience of a group of senior medical health risk assessors who had worked with a variety of these systems. The assigned incidence (risk) levels—high, medium, or low—are used to estimate the model component costs.

Table 3-1. System-Assigned Risk Levels

System category	Assigned risk level
Armored fighting vehicles	High
Engineer and logistics equipment	High
Missile artillery	High
Tube artillery	High
Air defense systems	Medium
Aircraft technology and armament	Medium
Ground antitank weapons	Medium
Infantry weapons	Medium

Table 3-1. System-Assigned Risk Levels (Continued)

System category	Assigned risk level
Other	Medium
Smokes and obscurants	Medium
Chemical defense equipment	Low
Clothing and individual equipment	Low
Communications, command, and control	Low
Surveillance, fire control, and electronic warfare	Low
Training devices	Low

Source: USACHPPM historical health hazard assessment data.

Number of Clinic Visits (N_c)

The number of visits (N_c) by injured or ill persons is based on the hazard severity category. Remember that the hazard severity category determines the seriousness of the medical outcomes that could occur. As the severity increases, the number of clinic visits increases.

For this cost component, based on values selected by a panel of experts, we assigned the number of visits based on the hazard severity category and the potential medical outcomes. For a hazard severity of Category I, we assigned a visit value of $N_c = 5$ visits; for a hazard severity of Category II, we assigned a visit value of $N_c = 3$ visits; for a hazard severity of Category III, we assigned a visit value of $N_c = 2$ visits; and for a hazard severity of Category IV, we assigned a visit value of $N_c = 1$ visit for use in the model.

OTHER USEFUL OUTPUTS

In addition to the yearly and life-cycle clinic costs that can be estimated, this component of the model can be used to estimate

- the number of persons injured or ill, and
- the number of clinic visits.

Number of Persons Injured or Ill (N_i)

We can determine the number of persons injured or ill (N_i) by using Equation 3-2:

$$N_i = N_e \times S_k \times I_i, \qquad \text{[Eq. 3-2]}$$

where

N_i = number of persons injured or ill,
N_e = total number of persons per year exposed for the systems or items,
S_k = hazard severity factor based on the determined hazard severity category, and
I_i = incidence of injury or illness based on the determined risk level for the individual materiel item.

Number of Clinic Visits (N_v)

We can determine the number of clinic visits (N_v) by using Equation 3-3:

$$N_v = N_e \times S_k \times \left[V_e + \left(I_i \times N_c\right)\right], \qquad \text{[Eq. 3-3]}$$

where

N_v = total number of clinic visits,
N_e = total number of persons per year exposed for the systems or items,
S_k = hazard severity factor based on the determined hazard severity category,
V_e = visit constant as result of exposure,
I_i = incidence of injury or illness based on the determined risk level for the individual item of materiel, and
N_c = number of visits by injured or ill personnel based on the determined hazard severity category.

These outputs may be useful to physicians, environmental engineers, environmental scientists, and other health care professionals as a basis for assessing the strengths and weaknesses of preventive health care. The measures may also be useful in trend analyses to identify which types of systems are more hazardous to operate and create the greatest burden on the health care system. This allows focusing corrective actions on the most hazardous systems currently in the inventory and preventive actions on similar types of systems in development.

Medical treatment facility commanders may use the illness and injury data to tailor their treatment capability to meet the demand. Preventive medicine program managers may use the outputs to evaluate the effectiveness of their program.

An Example Calculation

Continuing the example introduced in the previous chapter, System X has a weapons combustion products health hazard. For this hazard, System X has a RAC of 1, a hazard severity of Category I, and a hazard probability of A. We will

calculate clinic costs, the number of people injured or ill, and the number of clinic visits. Our known variables are

N_e = 26,640 persons per year exposed,
S_k = 1,
V_e = 0.75 visit per person,
I_i = 0.122,
N_c = 5 visits per person, and
F_c = \$122 per visit.

Using Equation 3-1 we see that total clinic costs (C_c) equal \$4,420,060 per year.

$$\begin{aligned} C_c &= N_v \times F_c \\ &= 36{,}230\ \textit{visits/year} \times \$122/\textit{visit} \\ &= \$4{,}420{,}060/\textit{year}. \end{aligned}$$

Using Equation 3-2 we see that the number of people injured or ill (N_i) equals 3,250 persons per year.

$$\begin{aligned} N_i &= N_e \times S_k \times I_i \\ &= 26{,}640\ \textit{persons/year exposed} \times 1 \times 0.122 \\ &= 3{,}250\ \textit{persons/year}. \end{aligned}$$

Finally, using Equation 3-3 we see that the total number of clinic visits per year (N_v) equals 36,230.

$$\begin{aligned} N_v &= N_e \times S_k \times \left[V_e + \left(I_i + N_c\right)\right] \\ &= 26{,}640\ \textit{persons/year} \times 1 \\ &\quad \times \left[\left(0.75\ \textit{visit/person}\right) + \left(0.122 \times 5\ \textit{visits/person}\right)\right] \\ &= 36{,}230\ \textit{clinic visits/year}. \end{aligned}$$

SUMMARY

In this chapter we discussed the model component for clinic costs, the specific variables associated with calculating those costs, and how the component outputs may be useful, and we performed an example calculation. In the next chapter we will discuss the model component for hospitalization costs.

Chapter 4
Estimating Hospitalization Costs

In this chapter we present the component for potential hospitalization costs as a result of exposure to a health hazard that results in injury or illness. We define the equations developed for estimating these costs, discuss the variables in determining hospitalization costs and the rationale and assumptions made, discuss other useful outputs, and perform an example calculation of hospitalization costs based on our System X example (using the single hazard).

The primary sources of our hospitalization-related data was the USACHPPM *Medical Surveillance Monthly Report,* April 1995, [18,19,20,21] and "CHAMPUS DRG Weights for Fiscal Year 1996" published in the *Federal Register.* [3]

THE EQUATION

This section describes the general equation for hospitalization costs and its variables. Hospitalization costs (C_h) are equal to the product of the number of hospital days (N_h) and the average fee per hospital day (F_h). The general equation is provided as Equation 4-1:

$$C_h = N_h \times F_h, \qquad \text{[Eq. 4-1]}$$

where

C_h = cost of hospitalization,
N_h = total number of hospital days, and
F_h = average fee per hospital day.

The hospital days variable (N_h) is dependent on two common variables and three unique variables. The two common variables, discussed in Chapter 2, are the number of people exposed and the severity of the hazard. The unique variables are the incidence of hospitalization (I_h), the average number of days in the hospital (D_{hd}) based on historical hospital length-of-stay distribution, and the hospital population distribution (D_{ho}). The hospital population distribution correlates directly with the factor for average number of days in the hospital.

The hospital fee variable (F_h) is an average cost based on various types of hospital diagnosis-related groups and the classification of the disease. We found the average hospital fee was $1,669 per day. [4]

SPECIFIC VARIABLES FOR HOSPITALIZATION COSTS

The specific variables we used in estimating hospitalization costs include the incidence of hospitalization (I_h), the average number of days in the hospital (D_{hd}), and the hospitalization population distribution (D_{ho}). We selected hospitalization incidence rates and the hospital population distribution from data in the USACHPPM *Medical Surveillance Monthly Report.* [18,19,20,21,22] It provides medical surveillance information of broad interest to the medical community. One of the areas of interest it routinely reports is Army active-duty hospitalization rates and hospital sick days by International Classification of Diseases (ICD) categories.

The data are current and concerned with active-duty military only. This is adequate for our use, as we are primarily concerned with soldiers operating weapon systems, and is comparable to using Bureau of Labor Statistics data. A disadvantage in using the hospital sick day data is that it includes bed days, convalescent sick days, and medical hold days. The ICD categories do not directly correlate with medical outcomes that could be expected with exposure to a health hazard. The ICD data are not directly comparable to the disability data categories or lost time data categories. These shortcomings do not present a problem in determining medical costs.

We selected illness and injury categories that correlate with the expected medical outcomes as a result of exposure to hazards within the nine health hazard categories. We also used the hospital sick day data to develop the hospitalization length-of-stay distribution matrix.

Incidence of Hospitalization (I_h)

We correlated selected classification of illness or injury diagnoses with the categories of health hazards. [18,19,20,21,22] These data represent the range of hospitalization rates within the Army for hazards associated with weapon systems. We assigned an appropriate incidence of hospitalization to the system categories, just as we did with the incidence of illness and injury. We assigned high-risk systems a hospitalization rate of 13 persons hospitalized per 1,000 soldiers per year. We assigned medium-risk systems a hospitalization rate of 7 persons hospitalized per 1,000 soldiers per year. We assigned low-risk systems a hospitalization rate of 5 persons hospitalized per 10,000 soldiers per year. We use the assigned incidence levels to calculate the model component costs.

Average Number of Days in Hospital (D_{hd})

The factor for the average number of days in the hospital (D_{hd}) is based on historical hospital length-of-stay data. [18,19,20,21,22] This approach provides realistic results and correlates directly with the hospitalization population distribution.

For this model component we assigned numerical values for the four average numbers of days in the hospital. These values appear in Table 4-1.

Table 4-1. Factors for Average Number of Days in Hospital (days/person)

Length of stay in hospital	Factor (D_{hd})
<2 days	1.0
2–5 days	3.5
6–30 days	18.0
>30 days	30.0

Hospitalization Population Distribution (D_{ho})

The factor for the hospitalization population distribution (D_{ho}) is based on historical data for the percentage of persons hospitalized for four selected hospital length-of-stay distribution categories. [18,19,20,21,22] This distribution approach, when combined with the factor for the average number of days in the hospital, provides a more realistic basis for determining the total number of hospital days.

For this model component we assigned numerical values for the four hospitalization population distribution factors. We assigned these factors to the appropriate system risk categories as shown in Table 4-2.

Table 4-2. Factors for Hospitalization Population Distribution (D_{ho}) by Length of Stay in Hospital for System Risk Categories

	Length of stay in hospital			
System risk category	<2 days	2–5 days	6–30 days	>30 days
High	0.40	0.35	0.17	0.08
Medium	0.40	0.36	0.18	0.06
Low	0.42	0.37	0.20	0.02

OTHER USEFUL OUTPUTS

In addition to the hospitalization costs, this component of the model can estimate

- the number of persons hospitalized, and
- the number of hospital days.

Number of Persons Hospitalized (N_{ph})

We can determine the number of persons hospitalized (N_{ph}) by using Equation 4-2:

$$N_{ph} = N_e \times S_k \times I_h, \qquad \text{[Eq. 4-2]}$$

where

N_{ph} = number of persons hospitalized,
N_e = total number of persons per year exposed for the systems or items,
S_k = hazard severity factor based on the determined hazard severity category, and
I_h = incidence of hospitalization based on the determined risk level for the individual item of materiel.

Number of Hospital Days (N_h)

We can determine the number of hospital days (N_h) by using Equation 4-3:

$$N_h = N_e \times S_k \times I_h \times \sum\left(D_{hd} \times D_{ho}\right), \qquad \text{[Eq. 4-3]}$$

where

N_h = total number of hospital days,
N_e = total number of persons per year exposed for the systems or items,
S_k = hazard severity factor based on the determined hazard severity category,
I_h = incidence of hospitalization based on the determined risk level for the individual item of materiel,
D_{hd} = factor for the average number of days in hospital per person based on historical hospital stay distribution, and
D_{ho} = factor for the hospitalization population distribution for average number of days in hospital.

These hospitalization component outputs may be useful to physicians, environmental engineers, environmental scientists, and other health care professionals as a basis for assessing the strengths and weaknesses of preventive health care. The outputs may also be useful in trend analyses to identify the system health hazards that are creating the greatest burden on the health care system. This allows focusing on eliminating the worst hazards in systems currently in the inventory and instituting preventive actions on similar systems that are under development.

Medical treatment facility commanders may use the data to assess performance and how well prevention activities are incorporated within the health care system. The data may also be used to tailor treatment capability to meet the demand.

Preventive medicine program managers may use the measures to evaluate the effectiveness of their program.

AN EXAMPLE CALCULATION

We continue here with our previous System X example. The system was assigned a RAC of 1, a hazard severity of Category I, and a hazard probability of A. We will calculate hospitalization costs, the number of people hospitalized, and the number of hospital days. Our known variables are

N_e = 26,640 persons per year exposed;
S_k = 1;
I_h = 0.013;
D_{hd} = 1 day per person for less than 2 days, 3.5 days per person for 2 to 5 days, 18 days per person for 6 to 30 days, and 30 days per person for greater than 30 days;
D_{ho} = 0.4 for less than 2 days, 0.35 for 2 to 5 days, 0.17 for 6 to 30 days, and 0.08 for greater than 30 days; and
F_h = \$1,669 per day.

Using Equation 4-1, total hospitalization costs per year (C_h) are \$4,095,187.

$$\begin{aligned} C_h &= N_h \times F_h \\ &= 2{,}454\ \textit{days/year} \times \$1{,}669/\textit{day} \\ &= \$4{,}095{,}187/\textit{year}. \end{aligned}$$

Using Equation 4-2, the number of people hospitalized per year (N_{ph}) is 346.

$$\begin{aligned} N_{ph} &= N_e \times S_k \times I_h \\ &= 26{,}640\ \textit{persons/year exposed} \times 1 \times 0.013 \\ &= 346\ \textit{persons/year}. \end{aligned}$$

Finally, using Equation 4-3, the total number of hospital days per year (N_h) is 2,454.

$$\begin{aligned} N_h &= N_e \times S_k \times I_h \times \sum\left(D_{hd} \times D_{ho}\right) \\ &= 26{,}640\ \textit{persons/year} \times 1 \times 0.013 \times \Big[\big(1\ \textit{day/person} \times 0.40\big) \\ &\quad + \big(3.5\ \textit{days/person} \times 0.35\big) + \big(18\ \textit{days/person} \times 0.17\big) \\ &\quad + \big(30\ \textit{days/person} \times 0.08\big)\Big] \\ &= 2{,}454\ \textit{days/year}. \end{aligned}$$

SUMMARY

In this chapter we discussed the model component for hospitalization costs, the specific variables associated with calculating those costs, and how the component outputs may be useful, and we performed an example calculation. In the next chapter we will discuss the model component for lost time costs.

Chapter 5
Estimating Lost Time Costs

In this chapter we present the component for potential lost time costs as a result of exposure to a health hazard that results in injury or illness. We define the equations developed for estimating these costs, discuss the variables in determining lost time costs, the rationale and assumptions made, and other useful outputs, and we perform an example calculation of lost time costs based on our System X example (using the single hazard).

The primary sources of our lost time data are from the Bureau of Labor Statistics. These included *Results of Labor Statistics Survey on U.S. Occupational Injuries, Illnesses in 1993* [10] and tabular data on the percentage distribution of nonfatal occupational injuries and illnesses involving days away from work for 1992. [11,12,13]

THE EQUATION

This section discusses the general equation for lost time costs and its variables. Lost time costs (C_l) are equal to the product of the number of lost workdays (N_l), the average wage per day (W_d), and a wage fringe benefit factor (B_f). The general equation is provided as Equation 5-1:

$$C_l = N_l \times W_d \times B_f , \qquad \text{[Eq. 5-1]}$$

where

C_l = cost of days of lost time,
N_l = total number of lost workdays,
W_d = average wage per day, and
B_f = wage fringe benefit factor.

The lost workdays variable (N_l) is dependent on two common variables and three unique variables. The two common variables, discussed in Chapter 2, are the number of people exposed and the severity of the hazard. The unique variables include the incidence of lost time (I_l), the factor for the average number of lost workdays (D_{ld}) based on historical lost workday distribution, and the factor for the lost time population distribution (D_{lt}). The lost time population factor correlates directly with the factor for average number of lost workdays.

The average wage per day (W_d) is based on the salaries and numbers of persons drawing that salary for a selected group of personnel. We determined an average wage to be $53.97 per day. [5]

We assigned the fringe benefit factor (B_f) a value of 1.41. It is a standard factor within the government that is used for programming personnel budget requirements and is considered representative of other corporate benefit factors.

SPECIFIC VARIABLES FOR LOST TIME COSTS

The specific variables we used in estimating lost time costs include the incidence of lost time (I_l), the factor for the average number of days of lost time (D_{ld}), and the factor for the lost time population distribution (D_{lt}). We selected lost time incidence rates and the lost time population distribution from data in the Bureau of Labor Statistics survey for occupational injuries and illnesses. It contains historical data addressing incidence rates for occupational injuries and illnesses by standard industrial classification for industry divisions, as well as the distribution of lost time by nature of injury, body part affected, source of injury, and event or exposure leading to injury or illness. [10,11,12,13]

The data were current and concerned with days away from work as a result of an occupational illness or injury. The information was adequate for this project. The lost time categories do not directly correlate with medical outcomes that could be expected with exposure to a health hazard. The lost time data categories are not directly comparable to the hospitalization or disability data. These shortcomings, however, did not present a problem in determining medical costs. We used the data on the nature of injury or event leading to exposure and the data providing incidence rates of illness and injury by standard industrial classification (SIC).

We selected lost time categories by nature of injury or event leading to exposure that correlate to expected medical outcomes as a result of exposure to hazards within the nine health hazard categories. We also used the lost time data to develop a lost time distribution matrix.

Incidence of Lost Time (I_l)

We correlated selected Department of Labor illness or injury categories with the categories of health hazards. [10,11,12,13] We considered the data representative of the range of lost time rates within the Army for hazards associated with materiel systems. We assigned an appropriate incidence of lost time to the system categories, just as we did with the incidences of illness and injury and of hospitalization. We assigned high-risk systems a lost time rate of 55 persons per 1,000 soldiers per year. We assigned medium-risk systems a lost time rate of 54 persons per 1,000 soldiers per year. We assigned low-risk systems a lost time rate of 28

persons per 1,000 soldiers per year. We use the assigned incidence levels to estimate the costs for the model's lost time component.

Average Number of Days of Lost Time (D_{ld})

We base the factor for the average number of days of lost time (D_{ld}) on historical distribution data for lost workdays. [11,12,13] This approach provides realistic results and correlates directly with the lost time population distribution.

For this model component, we assigned numerical values to the four factors for the average number of days of lost time. The factors, appearing in Table 5-1, are the same as for the hospitalization length of stay.

Table 5-1. Factors for Average Number of Days of Lost Time (days/person)

Lost workdays	Lost time factor (D_{ld})
<2 days	1.0
2–5 days	3.5
6–30 days	18.0
>30 days	30.0

Lost Time Population Distribution (D_{lt})

We base the factor for lost time population distribution (D_{lt}) on historical data for the percentage of persons losing time for four selected lost workday distribution categories. [11,12,13] This distribution approach, when combined with the factor for the average number of days of lost time, provides a more realistic basis for determining the total number of lost workdays.

For this model component, we assigned numerical values for the four lost time population distribution factors. We assigned these factors to the appropriate system risk categories as shown in Table 5-2.

Table 5-2. Factors for Lost Time Population Distribution (D_{lt}) by Days of Lost Time for System Risk Categories

	Lost time			
System risk category	<2 days	2–5 days	6–30 days	>30 days
High	0.22	0.30	0.29	0.20
Medium	0.20	0.33	0.31	0.16
Low	0.15	0.43	0.38	0.04

Other Useful Outputs

In addition to the costs for lost time, this component of the model can be used to estimate

- the number of persons losing time, and
- the number of lost workdays.

Number of Persons Losing Time (N_{pl})

We can determine the number of persons losing time (N_{pl}) by using Equation 5-2:

$$N_{pl} = N_e \times S_k \times I_l , \qquad \text{[Eq. 5-2]}$$

where

N_{pl} = total number of persons losing time,
N_e = total number of persons per year exposed for the systems or items,
S_k = hazard severity factor based on the determined hazard severity category, and
I_l = incidence of lost time based on the determined risk level for the individual materiel item.

Number of Lost Workdays (N_l)

We can determine the number of lost workdays (N_l) by using Equation 5-3:

$$N_l = N_e \times S_k \times I_l \times \sum\left(D_{ld} \times D_{lt}\right), \qquad \text{[Eq. 5-3]}$$

where

N_l = total number of days lost workdays,
N_e = total number of persons per year exposed for the systems or items,
S_k = hazard severity factor based on the determined hazard severity category,
I_l = incidence of lost time based on the determined risk level for the individual materiel item,
D_{ld} = number of lost workdays per person based on historical lost workday distribution, and
D_{lt} = lost time population distribution based on average lost workday distribution.

These lost time outputs may be useful to physicians, environmental engineers, environmental scientists, and other health care professionals as a basis for

assessing the strengths and weaknesses of preventive health care. Preventive medicine program managers may use the outputs to evaluate the effectiveness of their program. They may also be useful in trend analyses to identify system-specific health hazards that degrade unit readiness and create the greatest burden on the health care system.

Program managers and unit commanders may use the data to assess the impact on unit readiness if a system were fielded without hazard abatement. The lost time data may be the most important data from a unit commander's perspective. Having soldiers away from the job decreases readiness. Should the length of time away from the job be significant, it may be necessary to acquire and train replacement personnel.

AN EXAMPLE CALCULATION

We now continue with our System X example. The system was assigned a RAC of 1, a hazard severity of Category I, and a hazard probability of A. We will calculate lost time costs, the number of people losing time, and the number of lost workdays. Our known variables are

N_e = 26,640 persons per year exposed;
S_k = 1;
I_l = 0.055;
D_{ld} = 1 day per person for less than 2 days, 3.5 days per person for 2 to 5 days, 18 days per person for 6 to 30 days, and 30 days per person for greater than 30 days;
D_{lt} = 0.22 for less than 2 days, 0.30 for 2 to 5 days, 0.29 for 6 to 30 days, and 0.20 for greater than 30 days;
W_d = \$53.97 per day; and
B_f = 1.41.

Using Equation 5-1, total lost time costs (C_l) equal \$1,392,614 per year.

$$
\begin{aligned}
C_l &= N_l \times W_d \times B_f \\
&= 18{,}300\ \mathit{days/year} \times \$53.97/\mathit{day} \times 1.41 \\
&= \$1{,}392{,}614/\mathit{year}.
\end{aligned}
$$

Using Equation 5-2, the number of people losing time (N_{pl}) equals 1,465 persons per year.

$$
\begin{aligned}
N_{pl} &= N_e \times S_k \times I_l \\
&= 26{,}640\ \mathit{persons/year\ exposed} \times 1 \times 0.055 \\
&= 1{,}465\ \mathit{persons/year}.
\end{aligned}
$$

Finally, using Equation 5-3, the total number of lost workdays per year (N_l) is 18,300.

$$\begin{aligned} N_l &= N_e \times S_k \times I_l \times \sum \left(D_{ld} \times D_{lt} \right) \\ &= 26{,}640 \ \mathit{persons/year} \times 1 \times 0.055 \left[\left(1 \ \mathit{day/person} \times 0.22 \right) \right. \\ &\quad + \left(3.5 \mathit{days/person} \times 0.30 \right) + \left(18 \ \mathit{days/person} \times 0.29 \right) \\ &\quad \left. + \left(30 \ \mathit{days/person} \times 0.20 \right) \right] \\ &= 18{,}300 \ \mathit{days/year}. \end{aligned}$$

SUMMARY

In this chapter we discussed the model component for lost time costs, the specific variables associated with calculating those costs, and how the component outputs may be useful, and we performed an example calculation. In the next chapter we will discuss the model component for disability costs.

Chapter 6
Estimating Disability Costs

In this chapter we present the component for potential disability costs as a result of exposure to a health hazard that results in injury or illness. We define the equations developed for estimating these costs; we discuss the variables in determining disability costs, the rationale and assumptions made, and other useful outputs; and we perform an example calculation of disability costs based on our System X example (using the single hazard).

The primary source for VA disability data was the U.S. Department of Veterans Affairs, National Center for Veteran Analysis and Statistics, Demographics Division. [23,24,25,26,27] A report by the Armed Forces Epidemiological Board Injury Prevention and Control Work Group provided information on active-duty temporary and permanent disability. [6]

THE EQUATION

We discuss in this section the general equation for disability costs and its variables. Disability costs consist of costs for delayed VA disability and more immediate active-duty disability. Active-duty disability is either temporary or permanent. Disability costs (C_{di}) are equal to the product of the number of people exposed (N_e) times the hazard severity factor (S_k) times the incidence of VA disability (I_v) times the VA disability adjustment factor (T_v) times the sum of the VA disability population distribution (D_v) times the VA disability compensation (B_v) *plus* the number of people exposed (N_e) times the hazard severity factor (S_k) times the incidence of active-duty temporary disability (I_t) times the active-duty temporary disability compensation (B_t) *plus* the number of people exposed (N_e) times the hazard severity factor (S_k) times the incidence of active-duty permanent disability (I_p) times the active-duty permanent disability compensation (B_p):

$$\begin{aligned} C_{di} \;=\; & N_e \times S_k \times I_v \times T_v \times \sum \left(D_v \times B_v\right) \times 12 \; \textit{months/year} \\ & + \left[\left(I_t \times B_t\right) + \left(I_p \times B_p\right)\right] \end{aligned} \qquad \text{[Eq. 6-1]}$$

where

C_{di} = cost of disabilities;
N_e = total number of persons per year exposed for the systems or items;

S_k = hazard severity factor based on the determined hazard severity category;
I_v = incidence of VA disability based on the determined risk level for the individual item of materiel, equipment, or weapon system;
T_v = VA disability adjustment factor for delayed disability;
D_v = VA disability population factor based on historical rate of disability distribution;
B_v = VA disability compensation per month per rate of disability;
I_t = incidence of active-duty temporary disability;
B_t = active-duty temporary disability compensation per year;
I_p = incidence of active-duty permanent disability; and
B_p = active duty permanent disability compensation per year.

The determination of disability costs (C_{di}) is dependent on two common variables and eight unique variables. The two common variables, discussed in Chapter 2, are the number of people exposed and the severity of the hazard. The unique variables include the incidences for VA disability (I_v), active-duty temporary disability (I_t), and active-duty permanent disability (I_p); the VA disability adjustment factor for delayed disability (T_v); the VA disability population (D_v) based on historical rate of disability distribution; and the disability compensation rates for VA disability (B_v), active-duty temporary disability (B_t), and active-duty permanent disability (B_p).

SPECIFIC VARIABLES FOR DISABILITY COSTS

We developed many variables in estimating disability costs. The specific incidence variables we used included the incidence of VA disability (I_v), the incidence of active-duty temporary disability (I_t), and the incidence of active-duty permanent disability (I_p); a VA disability adjustment factor (T_v) for disability received after leaving the military; the VA disability population (D_v) based on historical rate of disability distribution; and disability compensation rates for VA disability (B_v), active-duty temporary disability (B_t), and active-duty permanent disability (B_p). We selected disability incidence rates and the disability population distribution from VA and Army data.

The VA data contained historical data addressing the degree of disability by case for given disability diagnoses. [23,24,25] The data were current and concerned with compensation of veteran's disabilities. This information was adequate for this project. The disability categories did not directly correlate with medical outcomes that could be expected with exposure to a health hazard. The disability data categories were not directly comparable to the hospitalization or lost time data. However, this did not present a problem in determining medical costs.

Disability categories were selected that correlated to expected medical outcomes as a result of exposure to hazards within the nine health hazard categories. We

also used the data on degree of disability to develop a disability distribution matrix for the VA data.

The Army data provided limited compensation and active-duty disability information that was sufficient to allow selection of temporary and permanent incidence factors and appropriate compensation factors. [6]

Incidences of Disability

In this subsection we discuss the three disability incidence rates. They are the VA disability rate, the active-duty temporary disability incidence rate, and the active-duty permanent disability incidence rate.

INCIDENCE OF VA DISABILITY (I_V)

We selected the incidence of VA disability (I_v) from reports by the National Center for Veteran Analysis and Statistics involving disability compensation by class of major disability by combined degree. [23,24,25] The data were current as of March 1995. We correlated selected classification of illness or injury diagnoses with the categories of health hazards. These data represent the range of disability rates within the Army for hazards associated with weapon systems. We assigned an appropriate incidence of disability to the system categories, just as we did with the incidence of illness and injury. We assigned high-risk systems a disability rate of 32 persons disabled per 1,000 soldiers per year. We assigned medium-risk systems a disability rate of 12 persons disabled per 1,000 soldiers per year. We assigned low-risk systems a disability rate of 5 persons hospitalized per 100,000 soldiers per year. We use the assigned incidence levels to estimate the model component costs.

INCIDENCE OF ACTIVE-DUTY TEMPORARY DISABILITY (I_t)

We selected incidence of active-duty temporary disability (I_t) from a report by the Armed Forces Epidemiological Board Injury Prevention and Control Work Group on illness and injury. [6] Its report provided basic information on active-duty temporary and permanent disability compensation. For this incidence rate we selected a single incidence only because of the limited data presented in the report. We assigned an active-duty temporary disability incidence rate of 1 person disabled per 1,000 soldiers per year. We use the assigned incidence rate to estimate the model component costs.

INCIDENCE OF ACTIVE-DUTY PERMANENT DISABILITY (I_p)

We selected incidence of active-duty permanent disability (I_p) from the report by the Armed Forces Epidemiological Board Injury Work Group on illness and injury. [6] The report provided basic information on active-duty permanent disability. For this incidence rate we selected a single incidence only because of the

limited data presented in the report. We assigned an active-duty permanent disability incidence rate of 11 persons disabled per 1,000 soldiers per year. We use the assigned incidence rate to estimate the model component costs.

VA Disability Adjustment Factor (T_v)

The VA disability adjustment factor (T_v) reduces the VA disability population. VA disability is received by eligible veterans after leaving military service. One would likely see disabilities compensated by the VA only later in the life of a system. We assumed that for a system with an operational life of 20 years, VA disabilities could be expected at 15 years. Based on this assumption, we assigned a VA disability adjustment factor of 0.25.

VA Disability Population Distribution Factor (D_v)

The disability population distribution factor (D_v) is based on historical data for the percentage of persons disabled for four selected disability distribution categories. VA disability is established in 10 percent increments. [23,24,25] This distribution approach provides a realistic basis for determining the cost of disability.

For this model component we assigned numerical values for the four disability population distribution factors. We assigned these factors to the appropriate system risk categories as shown in Table 6-1.

Table 6-1. Factors for Disability Population Distribution (D_v) by Degree of Disability for System Risk Categories

	Degree of disability			
System risk category	10%	20%–50%	60%–90%	100%
High	0.44	0.42	0.10	0.04
Medium	0.44	0.44	0.09	0.03
Low	0.43	0.48	0.08	0.01

Disability Compensation Factors

In this subsection we discuss the three disability compensation rates. They are the VA disability compensation rate, the active-duty temporary disability compensation rate, and the active-duty permanent disability compensation rate.

VA Disability Compensation Factor (B_v)

We based the VA disability compensation (B_V) factor on historical data for selected degree of disability categories. [7,8] The approach, when combined with the VA disability population distribution factor for degree of disability, provides a realistic basis for determining the cost of disability.

For this model component we assigned numerical values for the four VA disability compensation factors by degree of disability population distribution factors as shown in Table 6-2. VA disability is paid for 10 percent disability increments.

Table 6-2. VA Disability Compensation Factors by Degree of Disability (B_v) (dollars/month/person)

Degree of disability	VA disability compensation factor (B_v)
10%	$91.00
20%–50%	$340.25
60%–90%	$915.50
100%	$1,865.00

ACTIVE-DUTY TEMPORARY DISABILITY COMPENSATION FACTOR (B_t)

We based the active-duty temporary disability compensation factor (B_t) on 1990 historical compensation costs for permanent and temporary disability in the three military services. [6] Using the data provides a more realistic basis for determining the cost of disability than just using VA data.

We found the average active-duty temporary disability compensation to be $9,242 per year per person. We assumed that the temporary disability list would remain constant—that is, as someone is removed from the list another person is added to it.

ACTIVE-DUTY PERMANENT DISABILITY COMPENSATION FACTOR (B_p)

We based the active-duty permanent disability compensation factor (B_p) on 1990 historical compensation costs for permanent and temporary disability in the three military services. [6] Using the data provides a more realistic basis for determining the cost of disability than just using VA data.

We found the average active-duty permanent disability compensation to be $12,864 per year per person.

OTHER USEFUL OUTPUTS

In addition to estimating disability costs, this component of the model can estimate the number of persons disabled. We can determine the number of persons disabled (N_{pd}) by using Equation 6-2:

$$N_{pd} = N_e \times S_k \times \left(T_v \times I_v + I_t + I_p\right), \qquad \text{[Eq. 6-2]}$$

where

> N_{pd} = total number of persons disabled,
> N_e = total number of persons per year exposed for the systems or items,
> S_k = hazard severity factor based on the determined hazard severity category,
> T_v = VA disability adjustment factor for delayed disability,
> I_v = incidence of VA disability based on the determined risk level for the individual materiel item,
> I_t = incidence of active-duty temporary disability, and
> I_p = incidence of active-duty permanent disability.

As with other outputs previously discussed, disability outputs may be useful to physicians, environmental engineers, environmental scientists, and other health care professionals as an indicator for assessing the strengths and weaknesses of preventive health care. The outputs may be useful for determining when disabilities occur in a soldier's career. They may also be useful in trend analyses to identify the system health hazards that create the greatest burden on the health care system. This along with the other measures discussed in previous chapters allows focusing on eliminating the worst hazards in systems currently in the inventory and instituting preventive actions on similar systems in development.

Medical treatment facility commanders may use the data to assess performance and how well prevention activities are incorporated within the health care system. They may also use the data for trend analyses to assess the future burden on Army and VA health care systems.

Preventive medicine program managers may use this output to evaluate the effectiveness of their programs.

AN EXAMPLE CALCULATION

We now continue with our previous System X example. The system was assigned a RAC of 1, a hazard severity of Category I, and a hazard probability of A. We will calculate disability costs and the number of people disabled. Our known variables are

> N_e = 26,640 persons per year exposed;
> S_k = 1;
> I_v = 0.032;
> T_v = 0.25;
> D_v = 0.44 for 10 percent disability, 0.42 for disability between 20 percent and 50 percent, 0.10 for disability between 60 percent and 90 pecent, and 0.04 for a disability of 100 percent;

B_v = \$91.00 per month per person for a 10 percent disability, \$340.25 per month per person for a disability between 20 percent and 50 percent, \$915.50 per month per person for a disability between 60 percent and 90 percent, and \$1,865.00 per month per person for a disability of 100 percent;
I_t = 0.001;
B_t = \$9,242 per year per person;
I_p = 0.011; and
B_p = \$12,864 per year per person.

Using Equation 6-1, total disability costs (C_{di}) are equal to \$4,908,663 per year.

$$
\begin{aligned}
C_{di} &= N_e \times S_k \times \Big\{\Big[I_v \times T_v \times \sum(D_v \times B_v) \\
&\quad \times 12\ \textit{months/year}\Big] + \Big[(I_t \times B_t) + (I_p \times B_p)\Big]\Big\} \\
&= 26{,}640\ \textit{persons/year exposed} \times 1 \\
&\quad \times \Big\{\Big[0.032 \times 0.25 \times (0.44 \times \$91/\textit{month/person} \\
&\quad + 0.42 \times \$340.25/\textit{month/person} \\
&\quad + 0.1 \times \$915.50/\textit{month/person} \\
&\quad + 0.04 \times \$1{,}865/\textit{month/person}) \times 12\ \textit{month/year}\Big] \\
&\quad + \Big[(0.001 \times \$9{,}242/\textit{year/person}) \\
&\quad + (0.011 \times \$12{,}864/\textit{year/person})\Big]\Big\} \\
&= \$4{,}908{,}663/\textit{year}.
\end{aligned}
$$

Using Equation 6-2, the number of people disabled (N_{pd}) is 533 per year.

$$
\begin{aligned}
N_{pd} &= N_e \times S_k \times \Big[(T_v \times I_v) + (I_t \times I_p)\Big] \\
&= 26{,}640\ \textit{persons/year exposed} \times 1 \\
&\quad \times \big[(0.25 \times 0.032) + (0.001 + 0.011)\big] \\
&\quad + 533\ \textit{persons/year}.
\end{aligned}
$$

SUMMARY

In this chapter we discussed the model component for disability costs, the specific variables associated with calculating those costs, and how the component outputs may be useful, and we performed an example calculation. In the next chapter we will discuss the model components for rehabilitation costs.

Chapter 7
Estimating Rehabilitation Costs

In this chapter we present the component for potential rehabilitation costs as a result of exposure to a health hazard that results in injury or illness. We define the equations for estimating these costs, discuss the variables in determining rehabilitation costs and the rationale and assumptions made, discuss other useful outputs, and perform an example calculation of rehabilitation costs based on our System X example (using the single hazard).

The primary source of our rehabilitation-related data was the U.S. Department of Veterans Affairs fact sheets. [7,8,9]

THE EQUATION

In this section we discuss the general equation for rehabilitation costs and its variables. As shown in Equation 7-1, rehabilitation costs (C_r) are equal to the product of the number of people exposed (N_e) times the hazard severity factor (S_k) times the incidence of VA disability (I_v) times the sum of the eligible VA population distribution (D_r) greater than 20 percent times the rehabilitation qualification factor (Q_r) times the veteran rehabilitation benefit factor (B_r):

$$C_r = N_e \times S_k \times I_v \times T_v \times \sum D_r \times Q_r \times B_r, \qquad \text{[Eq. 7-1]}$$

where

- C_r = cost of rehabilitation,
- N_e = total number of persons per year exposed for the systems or items,
- S_k = hazard severity factor based on the determined hazard severity,
- I_v = incidence of VA disability based on the determined risk level for the individual item of materiel,
- T_v = VA disability adjustment factor for delayed disability,
- D_r = eligible VA disability population based on rate of disability distribution equal to or greater than 20 percent,
- Q_r = VA rehabilitation qualification factor, and
- B_r = VA rehabilitation benefit per year per person.

The determination of rehabilitation costs (C_r) is dependent on two common variables and five unique variables. The two common variables, as discussed in Chapter 2, are the number of people exposed and the severity of the hazard. The unique variables include the incidence of VA disability (I_v), the VA disability adjustment factor (T_v), the eligible VA population distribution (D_r) based on the

historical rate of VA disability distribution equal to or greater than 20 percent, the qualification factor for rehabilitation (Q_r), and the rehabilitation benefit factor (B_r).

We assumed the qualification factor for rehabilitation (Q_r) to be 5 percent of those persons having disabilities 20 percent or greater, and we estimated the rehabilitation benefit factor (B_r) to be $12,000 per year per person.

SPECIFIC VARIABLES FOR REHABILITATION COSTS

The specific variables we used in estimating rehabilitation costs include the incidence of VA disability (I_v), the VA disability adjustment factor (T_v), the eligible VA population distribution (D_r) based on the historical rate of VA disability distribution equal to or greater than 20 percent, the qualification factor for rehabilitation (Q_r), and the rehabilitation benefit factor (B_r).

Incidence of VA Disability (I_v)

We selected the incidence of VA disability (I_v) from the National Center for Veteran Analysis and Statistics database reports, as previously discussed in Chapter 6. [23,24,25] We assigned an active-duty permanent disability incidence of 32 persons disabled per 1,000 soldiers per year.

VA Disability Adjustment Factor (T_v)

The VA disability adjustment factor (T_v) reduces the VA disability population. As discussed in Chapter 6, VA disability is received by eligible veterans after leaving military service. We assigned a VA disability adjustment factor of 0.25.

Eligible VA Disability Population Distribution Factor (D_r)

As discussed in Chapter 6, we selected the factor for the eligible VA disability population distribution (D_r) based on historical data for the percentage of persons disabled for three selected disability distribution categories. [23,24,25] Eligibility for rehabilitation is limited to people with a disability of 20 percent or more. This distribution approach provides a more realistic basis for determining the cost of rehabilitation.

We assigned a disability population distribution factor of 0.42 for disability between 20 percent and 50 percent, 0.10 for disability between 60 percent and 90 percent, and 0.04 for a disability of 100 percent.

VA Qualification Factor for Rehabilitation (Q_r)

We assumed the qualification factor for rehabilitation (Q_r) to be 0.05. We selected this value based on an estimate of the percentage of people who may apply for and be accepted for rehabilitation benefits. The qualification factor selected may be low; for example, the Baltimore VA region estimated its acceptance rate for the VA rehabilitation program to be greater than 20 percent. However, the value is adequate for use in this model.

VA Rehabilitation Benefit Factor (B_r)

We estimated the rehabilitation benefit factor (B_r) to be \$12,000 per year per person. Rehabilitation benefits may vary per person, but we considered \$12,000 to be a reasonable estimate. Other benefits may be available for eligible disabled persons, but we did not consider these other benefits. [8,9]

OTHER USEFUL OUTPUTS

In addition to estimating rehabilitation costs, this component of the model estimates the number of persons rehabilitated. We can determine the number of rehabilitation cases (N_r) by using Equation 7-2:

$$N_r = N_e \times S_k \times I_v \times T_v \times \sum D_r \times Q_r , \qquad \text{[Eq. 7-2]}$$

where

- N_r = total number of rehabilitation cases,
- N_e = total number of persons per year exposed for the systems or items,
- S_k = hazard severity factor based on the determined hazard severity,
- I_v = incidence of VA disability based on the determined risk level for the individual materiel item,
- T_v = VA disability adjustment factor for delayed disability,
- D_r = eligible VA disability population based on rate of disability distribution equal to or greater than 20 percent,
- Q_r = VA rehabilitation qualification factor, and
- B_r = VA rehabilitation benefit per year per person.

As with other outputs previously discussed, rehabilitation outputs may be useful to physicians, environmental engineers, environmental scientists, and other health care professionals as an indicator for assessing the strengths and weaknesses of preventive health care. The outputs can be useful for determining what types of disabilities require rehabilitation. They may also be useful in trend analyses to identify the system health hazards creating the greatest burden on the health care system. These outputs, along with the others discussed in previous chapters,

allow focusing on eliminating the worst hazards in systems currently in the inventory and instituting preventive actions on similar systems in development.

Medical treatment facility commanders may use the data to assess performance and how well prevention activities are being incorporated within the health care system. They may also use the data for trend analyses to assess the future burden on Army and VA health care systems.

Preventive medicine program managers may use this output to evaluate the effectiveness of their programs.

An Example Calculation

We continue here with our previous System X example. The system was assigned a RAC of 1, a hazard severity of Category I, and a hazard probability of A. We will calculate rehabilitation costs and the number of people rehabilitated. Our known variables are

- N_e = 26,640 persons per year exposed;
- S_k = 1;
- I_v = 0.032;
- T_v = 0.25;
- D_v = 0.42 for disability between 20 percent and 50 percent, 0.10 for disability between 60 percent and 90 percent, and 0.04 for a disability of 100 percent;
- Q_r = 0.05; and
- B_r = \$12,000 per year per person.

Using Equation 7-1, total rehabilitation costs (C_r) are \$71,608 per year.

$$\begin{aligned} C_r &= N_e \times S_k \times I_v \times T_v \times \sum D_v \times Q_r \times B_r \\ &= 26{,}640 \textit{ persons/year exposed} \times 1 \times 0.032 \times 0.25 \\ &\quad \times [0.42 + 0.1 + 0.04] \times 0.05 \times \$12{,}000/\textit{person} \\ &= \$71{,}608/\textit{year}. \end{aligned}$$

Using Equation 7-2, the number of rehabilitation cases is 6 persons per year.

$$\begin{aligned} N_r &= N_e \times S_k \times I_v \times T_v \sum D_v \times Q_r \\ &= 26{,}640 \textit{ persons/year exposed} \times 1 \times 0.032 \times 0.25 \\ &\quad \times [0.42 + 0.1 + 0.04] \times 0.05 \\ &\quad + 6 \textit{ cases/year}. \end{aligned}$$

SUMMARY

In this chapter we discussed the model component for rehabilitation costs, the specific variables associated with estimating those costs, and how the component outputs may be useful, and we performed an example calculation. In the next chapter we will discuss the model component for death costs.

Chapter 8

Estimating Death Costs

In this chapter we present the component for potential death costs as a result of exposure to a health hazard that results in injury or illness. We define the equations for estimating these costs, discuss the variables in determining death costs and the rationale and assumptions made, discuss other useful outputs, and perform an example calculation of death costs based on our System X example (using the single hazard).

The primary source of death-related data was a report by the Armed Forces Epidemiological Board Injury Prevention and Control Work Group [6] and the death benefit paid by the Serviceman's Group Life Insurance.

THE EQUATION

In this section we discuss the general equation for death costs and its variables. As shown in Equation 8-1, death costs (C_{de}) are equal to the product of the number of deaths (N_{de}) and the death benefit and expenses (B_{de}):

$$C_{de} = \left(N_{de} \times B_{de}\right), \qquad \text{[Eq. 8-1]}$$

where

C_{de} = cost of death,
N_{de} = number of deaths per year, and
B_{de} = death benefit and expenses.

The cost of death variable (C_{de}) is dependent on two specific variables: the number of deaths (N_{de}) and the death benefit and expenses (B_{de}).

SPECIFIC VARIABLES FOR DEATH COSTS

The specific variables we used in estimating death costs are the number of deaths (N_{de}) and the death benefit and expenses (B_{de}). We selected values for the number of deaths after review of the report by the Armed Forces Epidemiological Board Injury Prevention and Control Work Group. [6]

Number of Deaths (N_{de})

We assumed that a potential for death existed only in the catastrophic hazard severity category. Easy and reliable sources of data were limited; this is an area requiring further research to establish other data sources and refine our model. The report by the Armed Forces Epidemiological Board Injury Prevention and Control Work Group showed that overall there was approximately 1 death per 1,000 clinic visits. While this number is appropriate from an overall injury perspective, the results obtained when applied to our example were not believable. [6] We assumed that only rare circumstances would allow more than 1 death per year related to a materiel system before an immediate resolution occurred.

For this model component we assigned a numerical value of 1 death for hazard severity Category I and a value of zero for all other hazard severity categories.

Death Benefit and Expenses (B_{de})

The cost of a person's death is not easily calculated and is another area deserving further research to establish other data sources and refine our model. The cost of death includes costs paid by insurance policies plus expenses relating to casualty assistance, honor guard, funeral and burial, family, and other related expenses. The military also incurs additional costs for training of replacement personnel. Serviceman's Group Life Insurance can pay a beneficiary up to $200,000 for the death of a soldier. Other expenses incurred by the Army can be substantial.

For this model component we assigned a numerical value of $200,000 for the death benefit and expenses factor.

OTHER USEFUL OUTPUTS

Another useful output is the number of deaths; however, as previously discussed, this area requires further research to establish other data sources and refine our model. Currently we assume the number of deaths equals 1 for a hazard severity of Category I and zero for all other hazard severity categories.

As with other outputs previously discussed, death outputs may be useful to physicians, environmental engineers, environmental scientists, and other health care professionals as an indicator for assessing the strengths and weaknesses of preventive health care. The outputs can be useful in trend analyses to identify the system health hazards that are creating the greatest burden on the health care system. These outputs, along with the others discussed in previous chapters, allow focusing on eliminating the worst hazards in systems currently in the inventory and instituting preventive actions with similar systems in development.

Medical treatment facility commanders may use the data to assess performance and how well prevention activities are being incorporated within the health care system. They may also use the data for trend analyses to assess the future burden on Army and VA health care systems.

Preventive medicine program managers may use these outputs to evaluate the effectiveness of their program.

AN EXAMPLE CALCULATION

We continue here with our previous System X example. The system was assigned a RAC of 1, a hazard severity of Category I, and a hazard probability of A. We will calculate the death costs. Our known variables are

> N_{de} = 1 death per year for a catastrophic hazard severity category, and
> B_{de} = \$200,000 per death.

Using Equation 8-1, death costs (C_{de}) are equal to \$200,000 per year.

$$
\begin{aligned}
C_{de} &= N_{de} \times B_{de} \\
&= 1\ \textit{death/year} \times \$200{,}000/\textit{death} \\
&= \$200{,}000/\textit{year}.
\end{aligned}
$$

As previously discussed, the number of deaths is equal to 1 per year.

SUMMARY

In this chapter we discussed the model component for death costs, the specific variables associated with estimating those costs, and how the component outputs may be useful, and we performed an example calculation. In the next chapter we will test the model and provide summary costs for a system with multiple health hazards.

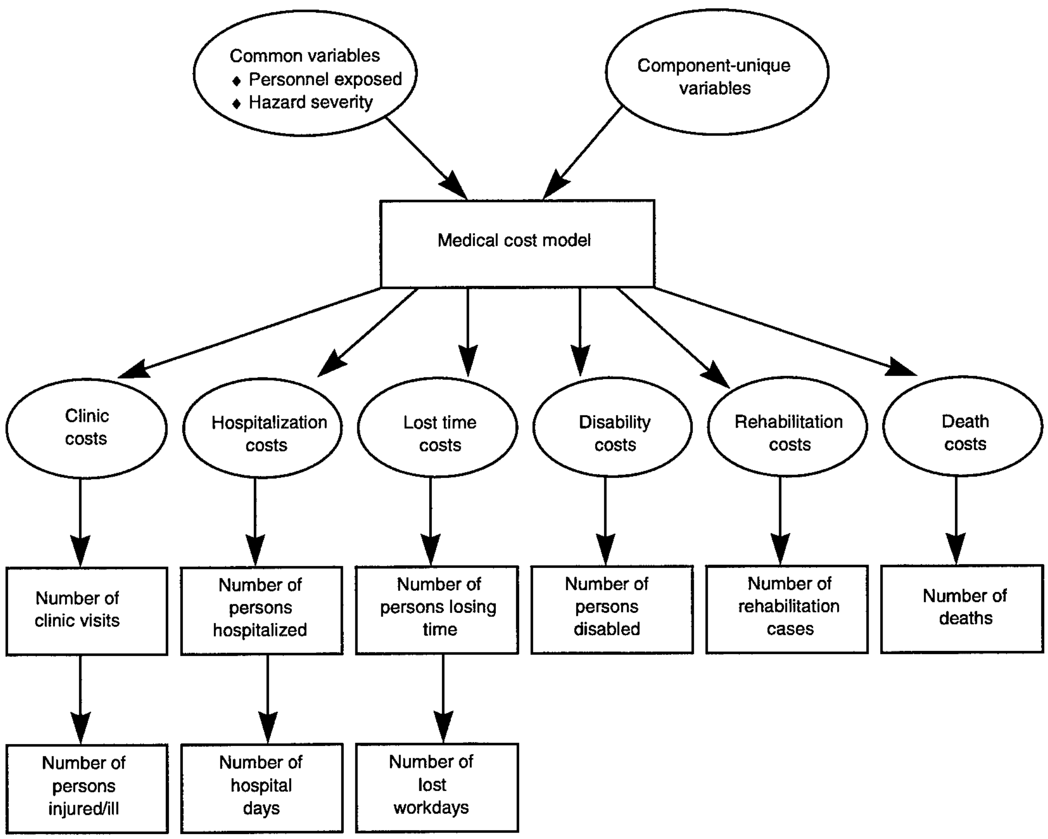
Chapter 9

Cost Summary for a System with Multiple Health Hazards

A Recap of the Model

In this chapter we summarize the total medical costs for all hazards identified for our System X. We discussed those hazards in Chapter 2; in subsequent chapters we explained the individual model components and provided sample calculations for each of the components for a single hazard. The model with the components and their individual outputs is shown in Figure 9-1.

Figure 9-1. The Basic Cost Model with Individual Components and Outputs



In this chapter we also summarize the component outputs and discuss how the cost and other output information may be used by program managers, health hazard assessors, medical treatment facility commanders, and other preventive medicine personnel.

TOTAL COSTS

In this section we calculate the total medical costs for all hazards identified for our System X.

Use of the Model for a System with Multiple Hazards

While earlier example calculations addressed only a single hazard, most materiel systems carry more than one health hazard. To calculate total medical costs for a system with multiple health hazards, we sum the individual component costs for each individual hazard. We identified 10 health hazards with System X. Table 9-1 lists them and their assigned risk indices.

Table 9-1. System X Health Hazards and Associated Risk Indices

Hazard category	Hazard	Risk Assessment Code (RAC)	Hazard severity category	Hazard probability
Chemical substances	Weapons combustion products	1	I	A
Chemical substances	Fire extinguishing agents	2	II	C
Chemical substances	Carbon dioxide	3	II	D
Acoustical energy	Impulse noise	2	II	C
Acoustical energy	Steady-state noise	2	II	C
Temperature extremes	Cold stress	2	II	C
Temperature extremes	Heat stress	2	II	C
Oxygen deficiency	Oxygen deficiency (ventilation)	2	II	C
Radiation energy	Nonionizing radiation	2	II	C
Radiation energy	Ionizing radiation	4	II	E

Cost Summary

Costs incurred over the operational life of the system as a result of unabated health hazards are significant—in this case, greater than $345 million. Lost time, disability, rehabilitation, and death costs of $150 million, along with clinic and hospitalization costs of $195 million, affect both readiness and the health care system. Table 9-2 summarizes the model component life-cycle costs for each of

the 10 unabated health hazards for System X. The table lists the hazards by the magnitude of their potential costs. Health hazard intervention and other preventive medicine measures can reduce these costs.

Table 9-2. Life-Cycle Costs of Unabated Health Hazards for System X

Hazards by rank	Costs ($000)						
	Clinic	Hospital	Lost time	Disability	Rehabilitation	Death	Total
Weapons combustion products	88,402	81,904	27,852	98,173	1,432	4,000	301,763
Fire extinguishing agents	1,612	1,820	619	2,182	32	0	6,265
Impulse noise	1,612	1,820	619	2,182	32	0	6,265
Steady-state noise	1,612	1,820	619	2,182	32	0	6,265
Cold stress	1,612	1,820	619	2,182	32	0	6,265
Heat stress	1,612	1,820	619	2,182	32	0	6,265
Oxygen deficiency (ventilation)	1,612	1,820	619	2,182	32	0	6,265
Nonionizing radiation	1,612	1,820	619	2,182	32	0	6,265
Carbon dioxide	81	91	31	109	2	0	314
Ionizing radiation	8	9	3	11	0	0	31
Total	99,775	94,744	32,219	113,567	1,658	4,000	345,963

Information presented in the form of Table 9-2 may be used by program managers, health hazard assessors, medical treatment facility commanders, and other preventive medicine personnel.

- Program managers can easily see which health hazards require immediate attention and priority abatement. They can also see that the magnitude of the costs could have a severe impact on readiness if the hazards are not eliminated or controlled.

- Health hazard assessors can show the value of their work and where needless medical costs can be avoided. They can see where they have to focus their attention concerning health hazard control education.

- Health care system practitioners can see which medical cost categories are most affected. This may assist medical treatment facility commanders in determining necessary resource reallocation within their medical treatment facility.

- Preventive medicine personnel can use information in the table to assist commanders in determining what health promotion and preventive education measures are required. The information can indicate where they

should focus efforts to reduce medical costs and the burden on the health care system. They can also use this information to evaluate the effectiveness of their programs in reducing medical costs—a reduction in medical costs is a measure of success. As the model is tested, other valuable uses for the information may become apparent.

While the average-hazard approach may mask hazard-specific differences in medical cost categories, it can be seen from Table 9-2 that this characteristic does not lessen the model's usefulness. However, improving the model to estimate hazard-specific costs needs to be pursued. Doing so would provide more detailed information on hazard-specific medical outcomes and impacts on specific hospital and clinic services, the types of injuries and illnesses occurring, and the hazards that create the most potential for lost time and disability. This improvement will require the research and development of individual hazard-specific variables for use in the model.

Individual Component Output Summary

The medical cost data clearly show that unabated health hazards can have a significant impact on readiness and the health care system over the operational life of System X. The individual component outputs give a detailed picture of these impacts. Table 9-3 summarizes the yearly individual component output data for each of the 10 unabated health hazards for System X. The table lists the hazards by the magnitude of their impact on readiness and the health care system.

Yearly, we can expect 3,758 injured or ill persons, 1,698 persons losing time at work, 618 disabled persons, and 402 hospitalized persons. This has a tremendous impact on available manpower. Lost workdays account for a total of 21,171 days per year. This directly impacts unit readiness. Yearly, we can expect 40,893 clinic visits and 2,842 hospital days as a result of exposure to health hazards resulting in illness and injury. This can present a great burden on the health care system. Health hazard intervention and other preventive medicine measures can reduce these costs.

Table 9-3 also provides information that may be used by program managers, health hazard assessors, medical treatment facility commanders, and other preventive medicine personnel. While the individual component outputs were selected based on the events that could occur as a result of an exposure to a health hazard resulting in illness or injury, it should become apparent that they are also measures of effectiveness for prevention programs.

Table 9-3. Individual Component Outputs by Hazard—Yearly Basis

Hazard	Component outputs								
	Clinic visits	Persons injured/ill	Persons hospitalized	Hospital days	Persons losing time	Lost work-days	Persons disabled	Rehabili-tation cases	Deaths
Weapons combustion products	36,230	3,250	346	2,454	1,465	18,300	533	7	1
Fire extin-guishing agents	661	72	8	55	33	407	12	0	0
Impulse noise	661	72	8	55	33	407	12	0	0
Steady-state noise	661	72	8	55	33	407	12	0	0
Cold stress	661	72	8	55	33	407	12	0	0
Heat stress	661	72	8	55	33	407	12	0	0
Oxygen deficiency ventilation	661	72	8	55	33	407	12	0	0
Nonionizing radiation	661	72	8	55	33	407	12	0	0
Carbon dioxide	33	4	0	3	2	20	1	0	0
Ionizing radiation	3	0	0	0	0	2	0	0	0
Total	40,893	3,758	402	2,842	1,698	21,171	618	7	1

Program managers can easily see the magnitude of injuries and lost workdays that will lessen readiness if the hazards are not eliminated or controlled. Health hazard assessors can identify preventable injuries and illnesses, lost time, and disabilities. They can also see where they have to focus their attention concerning health-hazard-control education. As with the medical cost information, health care system practitioners can see the impacts on clinic visits and hospital stays. This may assist medical activity commanders to determine resource reallocations among their clinical and preventive medicine services. Information such as that in Table 9-3 can also allow preventive medicine personnel to assist commanders in determining what health promotion and preventive education measures are required. As with medical costs, they can also use this information to evaluate the effectiveness of their programs, because a reduction in these output values is an indicator of success.

As we discussed earlier, improvements to address specific hazards will provide more detailed information on hazard-specific medical outcomes. This should

provide more information about the impacts on specific hospital and clinic services, the types of injuries and illnesses occurring, and the hazards with the most potential for injury, lost time, and disability.

While the current version of the model provides valuable information, it should be improved. We discuss future plans for the model in the next chapter.

Chapter 10
Increasing the Model's Value

The current model provides reasonable cost estimates by quantifying medical costs associated with unabated materiel system health hazards. Currently, USACHPPM's Health Hazard Assessment Office is testing an automated version of the cost model. We incorporated the model into its health hazard assessment database, and we developed a project officer module for USACHPPM personnel to use in performing health hazard assessments.

In this chapter we describe two ways to increase the value of the model: expanding its use throughout all areas of preventive medicine, and refining the model itself.

EXPANDING MODEL APPLICATION

While we developed this model specifically for the USACHPPM health hazard assessment program, it has applications in all areas of preventive medicine.

Other Preventive Medicine Programs

The concept of using the model for other preventive medicine programs is feasible. The health hazard assessment program is just one of 35 preventive medicine programs within USACHPPM. All of these programs focus on preventing disease and injury or promoting health. Disease and injury resulting from a health hazard triggers a series of possible outcomes: clinic visits, hospitalization, lost time, disability, and other consequences. These outcomes are no different from those used in our model.

The other programs within USACHPPM could use this model to estimate medical costs for recommendations made to eliminate health hazards within their technical specialty areas. For example, USACHPPM can apply the model directly in the evaluation of industrial operation work sites where health hazards are present. Industrial hygienists currently apply a risk assessment code to operations they evaluate. Health physicists could use the model to evaluate health hazards associated with medical treatment facility operations. Entomologists, physicians, and epidemiologists could estimate medical costs associated with vector-borne disease. Environmental engineers could gauge medical costs as a result of exposure to health hazards associated with hazardous waste sites, air pollution sources, or contaminated drinking water. Community health nurses could use the model to assess medical costs associated with smoking or improper nutrition. These are

just of few examples of how USACHPPM program managers could use the model.

Using the model in other programs may require adjusting or adding some variables and the individual component outputs. This would occur on a program-by-program basis.

Component Outputs

The Army could adopt the individual component outputs as performance metrics—measures of effectiveness—for prevention programs. The bottom line for prevention programs is to reduce the costs of clinic visits, hospitalization, lost time, disability, rehabilitation, and death. To do so, prevention programs could use the following outputs of the model as performance measures:

- Clinic visits
- Persons injured or ill
- Persons hospitalized
- Hospital days
- Persons losing time away from the job
- Lost workdays
- Persons disabled
- Rehabilitation cases
- Deaths.

IMPROVING THE MODEL

Improving the model would entail developing new cost components, better source data, and hazard-specific costs for making the component estimates.

Incorporating New Components

As previously discussed, we considered only medical costs for this version of the model. We did not address either the savings to the Army from preventing pollution to the environment or the cost involved with the actual implementation of the health hazard assessment recommendation. Adding cost components for pollution prevention and hazard abatement would improve the model's accuracy.

Pollution Prevention

The Army could develop typical default pollution prevention costs associated with elimination or control of hazards based on the types of recommendations made. Then it could gradually modify those default costs as more accurate pollution prevention costs become available. Continuously modifying the default costs with current pollution prevention costs will incrementally increase the model's accuracy.

Hazard Abatement

The Army could develop typical default hazard abatement costs associated with instituting various types of controls based on the categories of recommendations made.

We have begun categorizing recommendations using selected methods for control of toxic chemical, physical, and biological hazards. These include elimination, substitution, isolation, enclosure, ventilation, process change, product change, housekeeping, dust suppression, maintenance, sanitation, work practices, education, labeling and warning systems, personal protective equipment, environmental monitoring, waste disposal practices, administrative control, medical control, and management programs. There should be no more than five or six combined categories.

Improving Source Data

Three improvements to the source data would increase the model's accuracy: updating the data regularly, using Army data, and refining estimates of death costs.

Updating Data

Updating the source data as follows could improve the accuracy of the model:

- Updating the incidence rates for hospitalization, lost time, and disability periodically (e.g., yearly)
- Updating the population distribution factors for hospitalization, lost time, and disability periodically (e.g., yearly)
- Updating the cost variables for clinic and hospitalization fees, salaries, and disability compensation benefits.

Using Army Data

The use of additional actual Army data rather than health data for the U.S. population at large will improve the accuracy of the model's medical estimates. While

the source data we used were adequate for estimating component medical costs and were readily accessible, using Army data in the model would provide more accurate, Army-specific results.

Refining Death Component Costs

Death costs are an essential element of the estimated medical costs. The algorithm for estimating medical costs needs improvement.

An improved equation would incorporate hazard severity and hazard exposure probability. Adapting the "injury triangle" ratios developed by the Armed Forces Epidemiological Board Injury Work Group [6] would help improve calculation of death component costs.

Estimating Hazard-Specific Costs

The estimation of hazard-specific medical costs would improve the model.

For this initial version of the model, we decided to combine and average the data for the selected medical outcome (diagnostic) categories for all hazards. While this approach was more feasible for the study's time frame, averaging the data results in the loss of specific individual hazard cost estimates.

The Army could develop the appropriate incidence, distribution, and cost factors based on each hazard and its medical outcome categories. Each of the following types of data, based on the specific health hazard and its expected medical outcomes, would be needed:

- Incidence rates data for illness and injury, lost time, hospitalization, and disability
- Population distribution data for lost time, hospitalization, and disability
- Clinic visit costs by clinic service
- Hospitalization costs
- Disability costs.

Summary

In this chapter we have identified how wider application and better data could increase the value of the model. In the next chapter we present our recommendations for use of the model and its outputs, and we provide recommendations for improving the model.

Chapter 11
Recommendations

Based on our findings in developing and testing the model, we make recommendations in two general areas: applying the model to Army programs, and improving the accuracy of the model itself.

Applying the Model

We make the following recommendations for applying the model to USACHPPM and other Army programs:

- The USACHPPM Health Hazard Assessment Office should adopt the model to estimate medical costs for unabated health hazards and incorporate these costs into its reports.

  The current model provides reasonable cost estimates by quantifying medical costs associated with unabated materiel system health hazard assessment intervention.

- The USACHPPM Health Hazard Assessment Office should incorporate these costs into its health hazard assessment report recommendations.

  Quantifying health hazard costs improves the understanding of a stated health risk and assists system managers in making risk management decisions.

- The Army materiel program managers should use the results of the model to prioritize and abate health hazards associated with their systems.

  Using the results of the model would increase the effectiveness of the risk assessment and management process. Quantifying health hazard costs improves the system manager's understanding of the monetary impact of not implementing health hazard assessment recommendations. The model's lost time component identifies personnel time away from the job, an output directly relating to unit readiness.

- The Army preventive medicine community and the USACHPPM should adopt the model for use in all prevention-related programs, to determine the medical costs that are potentially avoided by individual mission program recommendations.

Exposure to the causes of disease and injury can trigger a series of possible events: clinic visits, hospitalization, lost time, disability, etc. These outcomes are the same as the ones used in this model. Using the model for other preventive medicine programs is feasible and highly advantageous.

- The Army preventive medicine community and the USACHPPM program managers should incorporate the component outputs as measures of effectiveness for prevention programs.

  The bottom line for prevention programs is or should be to reduce the personal, personnel and supply of health care costs of health hazards. These costs include death, disability, lost time, hospitalization, clinic visits, and rehabilitation. To assess the reduction in medical costs, prevention programs can use the model component outputs as performance indicators.

IMPROVING THE MODEL

We make the following recommendations for improving the scope and accuracy of the model:

- The USACHPPM should invest in incremental improvement of the model component variables, as described in this report.

  The model, while imperfect, is the first step toward estimating medical costs for unabated health hazards. It includes applicable costs and uses established databases internal and external to the Army.

- The USACHPPM should invest in incorporating new model components for pollution prevention and health hazard abatement.

  We did not address either the savings to the Army from preventing pollution to the environment or the cost involved with the actual implementation of the health hazard assessment recommendation. Adding cost components for pollution prevention and hazard abatement would improve the model's accuracy.

- The USACHPPM should invest in improving the source data used in the model.

  While the source data we used were adequate for estimating component medical costs, using additional actual Army data in the model would provide more accurate results.

- The USACHPPM should invest in developing appropriate variables to estimate hazard-specific costs.

  The ability to estimate hazard-specific medical costs would improve the model. The Army should develop the appropriate variables (i.e., incidence, distribution, and cost factors) based on each hazard and its medical outcome categories.

References

[1] Headquarters, Department of the Army, Army Regulation 40-10, *Health Hazard Assessment Program in Support of the Army Materiel Acquisition Decision Process*, 1991.

[2] "Medical and Dental Reimbursement Rates for Fiscal Year 1996," *Federal Register,* Volume 60, Number 195, 10 October 1996, pp. 52655—52659.

[3] "CHAMPUS DRG Weights for Fiscal Year 1996," Table 2, CHAMPUS Weights and Threshold Summary, *Federal Register,* Volume 60, Number 207, 26 October 1995, pp. 54851—54862.

[4] Walter Reed Army Medical Center (WRAMC), Third Party Collection Program, Memorandum to Gary M. Bratt, Logistics Management Institute, *Determining Cost of WRAMC Care,* Washington, DC, 4 December 1995.

[5] "The 1996 Army Times Pay Chart," *U.S. Army Times,* 20 November 1995.

[6] COL Bruce Jones, MD, and Barbara Hansen, Ph.D., et al., "Injuries in the Military: A Hidden Epidemic," Unpublished, A report for the Armed Forces Epidemiological Board, Injury Prevention and Control Work Group, November 1996.

[7] U.S. Department of Veterans Affairs, *Veterans Benefits, Fast Fact 1, Disability Compensation,* Washington, DC, 1994.

[8] U.S. Department of Veterans Affairs, *Federal Benefits for Veterans and Dependents,* Washington, DC, 1994 edition.

[9] U.S. Department of Veterans Affairs, *Veterans Benefits, Fast Fact 5, Vocational Rehabilitation (Chapter 31),* Washington, DC, 1994.

[10] U.S. Department of Labor, Bureau of Labor Statistics, *Results of Bureau of Labor Statistics Survey on U.S. Occupational Injuries, Illnesses in 1993,* Washington, DC, December 1994.

[11] U.S. Department of Labor, Bureau of Labor Statistics, *Results of Bureau of Labor Statistics Survey on U.S. Occupational Injuries, Illnesses in 1992.* Table 23, Percent Distribution of Nonfatal Occupational Injuries and Illnesses Involving Days Away from Work by Source of Injury or Illness and Number of Days Away from Work, 1992, Washington, DC, December 1993.

[12] U.S. Department of Labor, Bureau of Labor Statistics, *Results of Bureau of Labor Statistics Survey on U.S. Occupational Injuries, Illnesses in 1992*, Table 24, Percent Distribution of Nonfatal Occupational Injuries and Illnesses Involving Days Away from Work by Event or Exposure Leading to Injury or Illness and Number of Days Away from Work, 1992, Washington, DC, December 1993.

[13] U.S. Department of Labor, Bureau of Labor Statistics, *Results of Bureau of Labor Statistics Survey on U.S. Occupational Injuries, Illnesses in 1992*, Table 21, Percent Distribution of Nonfatal Occupational Injuries and Illnesses Involving Days Away from Work by Nature of Injury or Illness and Number of Days Away from Work, 1992, Washington, DC, December 1993.

[14] U.S. Army Center for Health Promotion and Preventive Medicine, *Health Hazard Assessment Database,* Aberdeen Proving Ground, MD, 1995 and 1996.

[15] U.S. Army Center for Health Promotion and Preventive Medicine, *U.S. Army Systems Health Hazards Manual—Procedures Guide,* Aberdeen Proving Ground, MD, 1994.

[16] Michael J. Konvalinka and Elizabeth B. Dial, *Understanding the Army Readiness Equipment Module (AREM)*, Unnumbered and unpublished introduction report, Logistics Management Institute, McLean, VA, April 1995.

[17] Michael J. Konvalinka and Elizabeth B. Dial, *Using the Army Readiness Equipment Module to Identify Problem Line Item Numbers,* Unnumbered and unpublished introduction report, Logistics Management Institute, McLean, VA, October, 1994.

[18] U.S. Army Center for Health Promotion and Preventive Medicine, "Table S1, Active Duty Hospitalizations, United States Army, 1994, by ICD-9 Category," *Medical Surveillance Monthly Report,* Aberdeen Proving Ground, MD, April 1995.

[19] U.S. Army Center for Health Promotion and Preventive Medicine, "Table S2, Active Duty Hospitalization Rates, United States Army, 1994, by ICD-9 Category," *Medical Surveillance Monthly Report,* Aberdeen Proving Ground, MD, April 1995.

[20] U.S. Army Center for Health Promotion and Preventive Medicine, "Table S3, Total Active Duty Hospital Sickdays, United States Army, 1994, by ICD-9 Category," *Medical Surveillance Monthly Report,* Aberdeen Proving Ground, MD, April 1995.

[21] U.S. Army Center for Health Promotion and Preventive Medicine, "Table S4, Non-Effective Rates, Active Duty Hospitalization, United States Army, 1994, by ICD-9 Category," *Medical Surveillance Monthly Report,* Aberdeen Proving Ground, MD, April 1995.

[22] U.S. Army Center for Health Promotion and Preventive Medicine, Memorandum to Gary M. Bratt, Logistics Management Institute, *Active Duty Army Hospitalizations 1994,* Aberdeen Proving Ground, MD, 1994.

[23] U.S. Department of Veterans Affairs, National Center for Veteran Analysis and Statistics, Demographics Division, Computer List, *Disability Compensation, Class of Major Disability by Combined Degree, Grand Total Report as of March 1995,* Washington, DC, undated.

[24] U.S. Department of Veterans Affairs, National Center for Veteran Analysis and Statistics, Demographics Division, Computer List, *Disability Compensation, Class of Major Disability by Combined Degree, Persian Gulf War Report as of March 1995,* Washington, DC, undated.

[25] U.S. Department of Veterans Affairs, National Center for Veteran Analysis and Statistics, Demographics Division, Computer List, *Specific Diagnosis, Major-Disability Compensation, Total Service Connected as of March 1995,* Washington, DC, undated.

[26] U.S. Department of Veterans Affairs, National Center for Veteran Analysis and Statistics, Demographics Division, "Numerical Index of Disabilities," 38 CFR, Chapter 1, Appendix B to Part 4, *Pensions, Bonuses and Veteran's Relief,* Washington, DC, July 1994.

[27] U.S. Department of Veterans Affairs, National Center for Veteran Analysis and Statistics, Demographics Division, "Alphabetical Index of Disabilities," 38 CFR, Chapter 1, Appendix C to Part 4, *Pensions, Bonuses and Veteran's Relief,* Washington, DC, July 1994.

Bibliography

"CHAMPUS DRG Weights for Fiscal Year 1996," Table 2, CHAMPUS Weights and Threshold Summary. *Federal Register.* Volume 60, Number 207. 26 October 1995. pp. 54851–54862.

Chapman, Larry S. *Proof Positive: An Analysis of the Cost-Effectiveness of Wellness.* Seattle, WA: Corporate Health Designs, 1995.

Cooper Institute for Aerobics Research. *Health Promotion and Cost Containment Strategies.* Briefing. Dallas, TX. 1994.

DeGaus, Stan. *U.S. Armed Forces Basic Training*. Reference Book NWC 3070. Newport, RI: U.S. Naval War College, August 1993.

Department of Defense, American Forces Information Service. *Defense 94,* Almanac. Issue 5. Alexandria, VA.

Department of Defense, American Forces Information Service. *Defense 95,* Almanac. Issue 5. Alexandria, VA.

Department of Defense, American Forces Information Service. *Defense 96,* Almanac. Issue 5. Alexandria, VA.

Department of Defense, Civilian Personnel Management Services. *General Schedule, Hourly and Overtime Rates for 1996.* Alexandria, VA. December 1995.

Department of Defense, Civilian Personnel Management Services. *Federal Wage System Regular and Special Production Facilitating Wage Rate Schedules for the Wage Area of Baltimore, Maryland.* Alexandria, VA. December 1994.

Headquarters, Department of the Army. Army Regulation 40-10, *Health Hazard Assessment Program in Support of the Army Materiel Acquisition Decision Process.* 1991.

Headquarters, Department of the Army, Office of the Assistant Secretary of the Army for Financial Management and Comptroller. *The Army Budget, 1996/1997 President's Budget.* April 1995.

Jones, COL Bruce, MD, and Barbara Hansen, Ph.D., et al., "Injuries in the Military: A Hidden Epidemic," Unpublished, A report for the Armed Forces Epidemiological Board, Injury Prevention and Control Work Group, November 1996.

Leutwyler, Kristin. "The Price of Prevention." *Scientific American.* April 1995.

Logistics Management Institute. *Understanding the Army Readiness Equipment Module (AREM).* Unnumbered and unpublished introduction report. Michael J. Konvalinka and Elizabeth B. Dial. McLean, VA. April 1995.

Logistics Management Institute. *Using the Army Readiness Equipment Module to Identify Problem Line Item Numbers.* Unnumbered and unpublished introduction report. Michael J. Konvalinka and Elizabeth B. Dial. McLean, VA. October 1994.

Logistics Management Institute. *Medical Technology Modernization and Strategic Planning: Shaping Army Health Care.* Report AR103R1. George L. Slyman and Gilbert L. Goldman. McLean, VA, January 1993.

"Medical and Dental Reimbursement Rates for Fiscal Year 1996." *Federal Register.* Volume 60, Number 195. 10 October 1996.

Pelletier, Kenneth R. "A Review and Analysis of the Health and Cost-Effective Outcome Studies of Comprehensive Health Promotion and Disease Prevention Programs at the Worksite: 1991–1993 Update." *American Journal of Health Promotion.* Vol. 8, No. 1. September/October 1993.

"Regulatory Impact, Regulatory Flexibility and Environmental Assessment of Revisions to Subpart I, Personal Protective Equipment." *Federal Register.* Volume 59, Number 66. 6 April 1994.

Retired Officers Association. *Planning for Military Retirement.* Alexandria, VA. 1991.

Rogers, Sandra. *Resource Allocation Methodology, Sentinel Health Event Analysis.* RAM-WN 93-1. Alexandria, VA: Systems Research and Applications Corporation, 1993.

"The 1996 Army Times Pay Chart." *U.S. Army Times,* 20 November 1995.

U.S. Army Aberdeen Proving Ground Installation Support Activity, Military Personnel Office. *Preretirement Briefing.* Aberdeen Proving Ground, MD. 1995.

U.S. Army Center for Health Promotion and Preventive Medicine. Data sheets, *Hearing Loss Cases and Compensation for Army Civilians—1983–1994.* Aberdeen Proving Ground, MD, Unpublished, undated.

U.S. Army Center for Health Promotion and Preventive Medicine. Data sheets, *Hearing Loss Cases and Compensation for Veterans—1986–1994.* Aberdeen Proving Ground, MD, Unpublished, undated.

U.S. Army Center for Health Promotion and Preventive Medicine. "Table S1, Active Duty Hospitalizations, United States Army, 1994, by ICD-9 Category." *Medical Surveillance Monthly Report.* Aberdeen Proving Ground, MD. April 1995.

U.S. Army Center for Health Promotion and Preventive Medicine. "Table S2, Active Duty Hospitalization Rates, United States Army, 1994, by ICD-9 Category." *Medical Surveillance Monthly Report.* Aberdeen Proving Ground, MD. April 1995.

U.S. Army Center for Health Promotion and Preventive Medicine. "Table S3, Total Active Duty Hospital Sickdays, United States Army, 1994, by ICD-9 Category." *Medical Surveillance Monthly Report.* Aberdeen Proving Ground, MD. April 1995.

U.S. Army Center for Health Promotion and Preventive Medicine. "Table S4, Non-Effective Rates, Active Duty Hospitalization, United States Army, 1994, by ICD-9 Category." *Medical Surveillance Monthly Report.* Aberdeen Proving Ground, MD, April 1995.

U.S. Army Center for Health Promotion and Preventive Medicine. Memorandum to Gary M. Bratt, Logistics Management Institute, *Active Duty Army Hospitalizations 1994.* November 20, 1995. Aberdeen Proving Ground, MD.

U.S. Army Center for Health Promotion and Preventive Medicine. *Health Hazard Assessment Database.* Aberdeen Proving Ground, MD, 1995 and 1996.

U.S. Army Center for Health Promotion and Preventive Medicine. *Benefit/Cost Analysis for Adenovirus (ADV) Types 4 and 7 Vaccines.* Memorandum. Aberdeen Proving Ground, MD. October 1995.

U.S. Army Center for Health Promotion and Preventive Medicine. *U.S. Army Systems Health Hazards Manual—Procedures Guide.* Aberdeen Proving Ground, MD. 1994.

U.S. Army Environmental Hygiene Agency. *Annual Historical Report—AMEDD Activities [RCS-MED 41 (R4)].* Aberdeen Proving Ground, MD. 1993.

U.S. Army Environmental Hygiene Agency. *Annual Historical Report—AMEDD Activities [RCS-MED 41 (R4)].* Aberdeen Proving Ground, MD. 1992.

U.S. Army Environmental Hygiene Agency. *Annual Historical Report—AMEDD Activities [RCS-MED 41 (R4)].* Aberdeen Proving Ground, MD. 1991.

U.S. Army Environmental Hygiene Agency. *Annual Historical Report—AMEDD Activities [RCS-MED 41 (R4)].* Aberdeen Proving Ground, MD. 1990.

U.S. Army Medical Command. *Preventive Medicine and Wellness Performance Indicators.* Briefing. Fort Sam Houston, TX. 1995.

U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, Epidemiology Program Office. "A Framework for Assessing the Effectiveness of Disease and Injury Prevention." *Morbidity and Mortality Report.* 27 March 1992.

U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, Epidemiology Program Office. "Estimated Expenditures for Core Public Health Functions—Selected States, October 1992–September 1993." *Morbidity and Mortality Report.* 9 June 1995.

U.S. Department of Labor, Bureau of Labor Statistics. *Results of Bureau of Labor Statistics Survey on U.S. Occupational Injuries, Illnesses in 1992.* Table 23. Percent Distribution of Nonfatal Occupational Injuries and Illnesses Involving Days Away from Work by Source of Injury or Illness and Number of Days Away from Work, 1992. Washington, DC. December 1993.

U.S. Department of Labor, Bureau of Labor Statistics. *Results of Bureau of Labor Statistics Survey on U.S. Occupational Injuries, Illnesses in 1992.* Table 24. Percent Distribution of Nonfatal Occupational Injuries and Illnesses Involving Days Away from Work by Event or Exposure Leading to Injury or Illness and Number of Days Away from Work, 1992. Washington, DC. December 1993.

U.S. Department of Labor, Bureau of Labor Statistics. *Results of Bureau of Labor Statistics Survey on U.S. Occupational Injuries, Illnesses in 1992.* Table 21. Percent Distribution of Nonfatal Occupational Injuries and Illnesses Involving Days Away from Work by Nature of Injury or Illness and Number of Days Away from Work, 1992. Washington, DC. December 1993.

U.S. Department of Labor, Office of Workers Compensation Programs, Division of Federal Employees Compensation. *Hearing Loss Compensation for Civilians, Charge Back Year 1 July 1993–30 June 1994.* Washington, DC. December 1993.

U.S. Department of Labor, Bureau of Labor Statistics. *Results of Bureau of Labor Statistics Survey on U.S. Occupational Injuries, Illnesses in 1993.* Washington, DC. December 1994.

U.S. Department of Veterans Affairs, *Federal Benefits for Veterans and Dependents,* Washington, DC, 1994 edition.

U.S. Department of Veterans Affairs, National Center for Veteran Analysis and Statistics, Demographics Division. "Numerical Index of Disabilities." 38 CFR, Chapter 1, Appendix B to Part 4. *Pensions, Bonuses and Veteran's Relief.* Washington, DC. July 1994.

U.S. Department of Veterans Affairs, National Center for Veteran Analysis and Statistics, Demographics Division. "Alphabetical Index of Disabilities." 38 CFR, Chapter 1, Appendix C to Part 4. *Pensions, Bonuses and Veteran's Relief.* Washington, DC. July 1994.

U.S. Department of Veterans Affairs, National Center for Veteran Analysis and Statistics, Demographics Division, Computer List. *Active Compensation, Pension, and Retirement Cases by Period of Service.* Washington, DC. March 1995.

U.S. Department of Veterans Affairs. National Center for Veteran Analysis and Statistics. Demographics Division, Computer List. *Disability Compensation, Class of Major Disability by Combined Degree. Grand Total Report as of March 1995.* Washington, DC.

U.S. Department of Veterans Affairs, National Center for Veteran Analysis and Statistics, Demographics Division, Computer List. *Disability Compensation, Class of Major Disability by Combined Degree, Persian Gulf War Report as of March 1995.* Washington, DC.

U.S. Department of Veterans Affairs, National Center for Veteran Analysis and Statistics. Demographics Division, Computer List. *Specific Diagnosis, Major-Disability Compensation, Total Service Connected as of March 1995.* Washington, DC.

U.S. Department of Veterans Affairs, National Center for Veteran Analysis and Statistics, Demographics Division. *Hearing Loss Compensation for Veterans—1994.* Washington, DC. July 1994.

U.S. Department of Veterans Affairs. *Veterans Benefits, Fast Fact 1, Disability Compensation.* Washington, DC, 1994.

U.S. Department of Veterans Affairs. *Veterans Benefits, Fast Fact 5, Vocational Rehabilitation (Chapter 31).* Washington, DC. 1994.

Walter Reed Army Medical Center (WRAMC). Third Party Collection Program. *Determining Cost of WRAMC Care.* Memorandum. Washington, DC. 4 December 1995.

Glossary

B_{de}—death benefit and expenses.

B_f—wage fringe benefit factor.

B_p—active-duty permanent disability compensation per year.

B_r—VA rehabilitation benefit per person.

B_t—active-duty temporary disability compensation per year.

B_v—VA disability compensation per month per rate of disability.

C_c—cost of clinic visits.

C_{de}—cost of death.

C_{di}—cost of disabilities.

C_h—cost of hospitalization.

C_l—cost of lost time.

clinic costs component—component of the model that estimates costs attributed to outpatient visits to the medical clinic or medical treatment facility by persons exposed to a hazard that resulted in illness or injury.

clinic costs component output—outputs that can be estimated other than costs. The specific outputs are the number of clinic visits and the number of persons who are injured or ill.

common variables—specific variables used in the estimate of costs in five of the six model components: clinic, hospitalization, lost time, disability, and rehabilitation. The specific variables are the number of persons exposed (N_e) and the hazard severity factor (S_k).

component-unique variables—specific variables that are unique to each model component and are used to determine component costs. They include incidence and distribution rates for lost time, hospitalization, disability, etc.

cost avoidance—medical costs not incurred because of health hazard intervention and prevention activities.

C_r—cost of rehabilitation.

D_{hd}—factor for average number of days in hospital per person based on historical hospital stay distribution.

D_{ho}—factor for hospitalization population distribution for average number of days in hospital.

disability costs component—component of the model that estimates costs attributed to active-duty temporary and permanent disability compensation, and VA disability compensation, for persons exposed to a hazard that resulted in illness or injury.

disability costs component output—outputs that can be estimated other than costs. The specific output is the number of persons who are disabled.

D_{ld}—number of lost workdays per person based on historical lost workday distribution.

D_{lt}—lost time population distribution based on average lost workday distribution.

D_r—eligible VA disability population based on rate of disability distribution equal to or greater than 20 percent.

D_v—VA disability population factor based on historical rate of disability distribution.

F_c—average fee per clinic visit.

F_h—average fee per hospital day.

hazard costs per year—costs of hazard per year based on hospitalization, lost time, disability, rehabilitation, and death costs.

hazard probability—the likelihood that a hazard will occur. It reflects the duration of exposure and the number of exposed personnel. There are five categories for hazard probability, designated A through E:

- **A, frequent**—likely to occur habitually for a specific individual item; will occur continuously for a fleet or inventory.
- **B, probable**—will occur several times in the life of a specific individual item; will occur frequently for a fleet or inventory.
- **C, occasional**—likely to occur sometime in the life of a specific individual item; will occur several times for a fleet or inventory.
- **D, remote**—unlikely but possible to occur sometime in the life of a specific individual item; unlikely but can reasonably be expected to occur for a fleet or inventory.

- **E, improbable**—so unlikely it can be assumed an occurrence may not be experienced in the life of a specific individual item; unlikely to occur but possible for a fleet or inventory.

hazard severity—an assessment of the potential consequence. It is used to address degree of bodily injury, illness, performance degradation, or bodily system damage that could occur. It reflects the magnitude of exposure to a hazard and the medical effects of the exposure. It is assessed prior to the implementation of recommendations to eliminate or minimize the hazard. There are four health hazard categories, designated I through IV:

- **I, catastrophic**—hazard may cause death or total loss of a bodily system.
- **II, critical**—hazard may cause severe bodily injury, severe occupational illness, or major damage to a bodily system.
- **III, marginal**—hazard may cause minor bodily injury, minor occupational illness, or minor damage to a bodily system.
- **IV, negligible**—hazard would cause less than minor bodily injury, minor occupational illness, or minor bodily system damage.

health hazard—an existing or likely condition, inherent to the operation or use of materiel, that can cause death, injury, acute or chronic illness, disability, or reduced job performance of personnel by exposure to acoustical energy, biological substances, chemical substances, oxygen deficiency, radiation energy, shock, temperature extremes, trauma, and vibration.

health hazard assessment—the application of biomedical knowledge and principles to document and quantitatively determine the health hazards of systems. This assessment identifies, evaluates, and recommends solutions to control the risks to the health and effectiveness of personnel who test, use, or service Army materiel systems. It includes the evaluation of hazard severity, hazard probability, risk assessment, and operational constraints; the identification of required precautions and protective devices; and the identification of training requirements.

health risk—combines the probability of exposure to a hazard and the severity of the potential consequences.

HHA—health hazard assessment.

hospitalization costs component—component of the model that estimates costs attributed to inpatient hospital stays by persons exposed to a hazard that resulted in illness or injury.

hospitalization costs component output—outputs that can be estimated other than costs. The specific outputs are the number of persons who are hospitalized and the number of hospital days.

HP—hazard probability.

HS—hazard severity.

ICD—International Classification of Diseases.

I_h—incidence of hospitalization based on the determined risk level for the individual item of materiel.

I_i—incidence of injury or illness based on the determined risk level for the individual item of materiel.

I_l—incidence of lost time based on the determined risk level for the individual item of materiel.

incidence rates—rate of injury or illness in a group over a period of time.

I_p—incidence of active-duty permanent disability.

I_t—incidence of active-duty temporary disability.

I_v—incidence of VA disability based on the determined risk level for the individual item of materiel.

lost time costs component—component of the model that estimates costs attributed to time away from the job by persons exposed to a hazard that resulted in illness or injury.

lost time costs component output—outputs that can be estimated other than costs. The specific outputs are the number of persons losing time away from the job and the number of lost workdays.

manpower and personnel integration—the process of integrating the full range of manpower, personnel training, human engineering, health hazard, system safety, and soldier survivability to improve individual performance and total system performance throughout the entire system development and acquisition process.

MANPRINT—manpower and personnel integration.

materiel—all items necessary to equip, operate, maintain, and support military activities, including ships, tanks, self-propelled weapons, aircraft, and related spares, repair parts, and support equipment, but excluding real property, installations, and utilities.

N_c—number of visits by injured or ill personnel based on the determined hazard severity category.

N_{de}—number of deaths per year.

N_e—total number of persons per year exposed for the materiel systems or items.

N_h—total number of hospital days.

N_i—number of persons injured or ill.

N_l—total number of lost workdays.

N_{pd}—total number of persons disabled.

N_{ph}—number of persons hospitalized.

N_{pl}—total number of persons losing time.

N_{ps}—number of persons per system (i.e., crew size for system or item).

N_s—number of systems (i.e., the total number of individual items of materiel systems in Army inventory).

N_v—total number of clinic visits as a result of exposure to a health hazard.

P_e—probability of exposure per year, based on the determined hazard probability category.

Q_r—VA rehabilitation qualification factor.

RAC—risk assessment code.

rehabilitation costs component—component of the model that estimates costs attributed to rehabilitation benefits received by eligible persons drawing VA disability compensation who were exposed to a hazard that resulted in illness or injury.

rehabilitation costs component output—outputs that can be estimated other than costs. The specific output is the number of rehabilitation cases.

SIC—standard industrial classification.

S_k—hazard severity factor based on the determined hazard severity category.

total medical costs—the sum of each cost component (clinic, hospitalization, lost time, disability, rehabilitation, and death).

T_v—VA disability adjustment factor for delayed disability.

USACHPPM—U.S. Army Center for Health Promotion and Preventive Medicine.

VA—U.S. Department of Veterans Affairs.

V_e—visit constant as a result of exposure to a health hazard.

W_d—average wage per day.

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A model was developed to assist the U.S. Army estimate weapon system health hazard costs based on the probability of a hazard occurring and the severity of that hazard. Nine health hazard categories were linked with potential medical outcomes. Incidence rates were researched and costs were calculated based on industry-wide injury, lost time, hospitalization, and disability data. These costs were then related to the existing health risk indices. This study recommends adopting the model, including the results in health hazard assessment reports, and using the results for abatement prioritization to better enable the Army to eliminate or control materiel health hazards and control life-cycle costs. Furthermore, it recommends applying the model to other areas of preventive medicine to provide invaluable quantitative cost savings and cost avoidance information to Army decision-makers.

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